DOCUMENT RESUME

ED 192 103 CE 026 661

TITLE	Nuclear Technology Series. Course 21: Radioactive Materials Disposal and Management.
INSTITUTION	Center for Occupational Research and Development, Inc., Waco, Tex.; Technical Education Research Center, Waco, Tex.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	80
CONTRACT	300-78-0582
NOTE	260p.; For related documents see CE 026 639-672, CE 026 779-780, CE 026 782-785, and CE 026 855-856.
AVAILABLE FROM	Center for Occupational Research and Development, 4800 Lakewood Dr., Suite 5, Waco, TX 76710 (Modules are available individually or by course; write for prices)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Energy; Learning Activities; Learning Modules; *Nuclear Energy; Postsecondary Education; Quality Control; *Technical Education; Technical Occupations; *Waste Disposal
IDENTIFIERS	Nuclear Energy Occupations; Nuclear Power Plants; Nuclear Technology; *Nuclear Wastes; *Radioactivity

ABSTRACT

This technical specialty course is one of thirty-five courses designed for use by two-year postsecondary institutions in five nuclear technician curriculum areas: (1) radiation protection technician, (2) nuclear instrumentation and control technician, (3) nuclear materials processing technician, (4) nuclear quality-assurance/quality-control technician, and (5) nuclear reactor (plant) operator trainee. This course, Radioactive Materials Disposal and Management, contains seven modules: Radioactive Waste Disposal Procedures, Routine Sampling of Radioactive Waste, Radioactive Waste Disposal Regulations, Measurement of External Radioactive Contamination, Regulations for Transportation of Radioactive Materials, Packaging and Monitoring of Radioactive Materials, Packaging and Monitoring of Radioactive Materials for Shipment, and Leak Tests of Sealed Radioactive Sources. Each module follows a typical format including the following sections: introduction, module prerequisites, objectives, subject matter, exercises, materials, procedures, data tables, reference materials, and tests. (A master index and suggested program planning guides are also available--see CE 026 856 and CE 026 639-643.) (LRA)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED192103

Nuclear Technology Series

COURSE 21

RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT INC.

4800 LAKEWOOD DRIVE
WACO, TEXAS 76710

CE 026 661

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

D. M. Hull

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

PREFACE

ABOUT NUCLEAR TECHNOLOGY MODULES

The modules – developed for use in two-year postsecondary technical institutions to prepare technicians for employment – are useful in industry for updating employees in company-sponsored training, and as laboratory texts in engineering schools. The principles, techniques and skills taught in the modules, based on tasks that nuclear technicians perform, were obtained from a nationwide advisory committee of employers of nuclear technicians. Each module was written by a working technical expert/experienced writer team and tested with students.

A module contains the following elements:

Introduction, which identifies the topic and often includes a rationale for studying the material.
Module Prerequisites, which identify the material a student should be familiar with before studying the module.
Objectives, which clearly identify what the student is expected to know for satisfactory module completion. The objectives, stated in terms of action-oriented behaviors, include such action words as operate, measure, calculate, identify and define, rather than words with many interpretations, such as know, understand, learn and appreciate.
Subject Matter, which presents the background theory and techniques supportive to the objectives of the module. Subject matter is written with the technical student in mind.
Exercises, which provide practical problems to which the student can apply this new knowledge.
Materials, which identify the equipment required to complete the laboratory procedure.
Procedures, which is the experiment section, or "hands-on" portion of the module (including step-by-step instruction) designed to reinforce student learning.
Data Tables, which are included in most modules for the first year (or basic) courses to help the student learn how to collect and organize data.
Reference Materials, which are included as suggestions for supplementary reading/viewing for the student.
Test, which measures the student's achievement of the prestated objectives.

A helpful Index has been added at the end of each course.

The materials contained herein were developed pursuant to a contract with the Office of Education, U.S. Department of Health, Education and Welfare: Contract No. 300780582. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

The Nuclear Technology Series consists of five curricula:

Nuclear Reactor (Plant) Operator Trainee.
Radiation Protection Technician.
Nuclear Materials Processing Technician.
Nuclear Quality-Assurance/Quality-Control Technician.
Nuclear Instrumentation and Control Technician.

The completed Nuclear Technology Series consists of the following 35 technical specialty courses:

Radiation Physics.
Radiation Protection I.
Principles of Process Instrumentation.
Heat Transfer and Fluid Flow.
Introduction to Nuclear Systems.
Instrumentation and Control of Reactors and Plant Systems.
Reactor Operations.
Reactor Safety.
Reactor Auxiliary Systems.
Power Plant Systems.
Radiation Detection and Measurement.
Reactor Physics.
Power Plant Chemistry.
Introduction to Quality Assurance/ Quality Control.
Metallurgy and Metals Properties.
Mechanical Component Characteristics and Specifications.
Radiation Protection II.
Radiological Emergencies.
Radiation Shielding.
Radiation Monitoring Techniques (Radiochemical).
Radioactive Materials Disposal and Management.
Advanced Radionuclide Analysis.
Nuclear Chemical Processes.
Nuclear Systems and Safety.
Radioactive Material Handling Techniques.
Nondestructive Examination (NDE) Techniques I.
Metrology.
Welding Inspection.
Civil/Structural Inspection.
Mechanical Inspection.
Quality-Assurance Practices.
Nondestructive Examination (NDE) Techniques II.
Control Systems I.
Control Systems II.
Power Plant Electrical Systems and Components.

Availability: Instructional modules are available individually or by courses from:

Center for Occupational Research and Development
4800 Lakewood Drive, Suite 5
Waco, Texas 76710
Telephone (817) 772-8756

Printed:

CONTENTS

COURSE 21 RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

Module 21-1	Radioactive Waste Disposal Procedures
Module 21-2	Routine Sampling of Radioactive Waste
Module 21-3	Radioactive Waste Disposal Regulations
Module 21-4	Measurement of External Radioactive Contamination
Module 21-5	Regulations for Transportation of Radioactive Materials
Module 21-6	Packaging and Monitoring of Radioactive Materials for Shipment
Module 21-7	Leak Tests of Sealed Radioactive Sources

NUCLEAR TECHNOLOGY

MODULE 21-1

RADIOACTIVE WASTE DISPOSAL AND MANAGEMENT

RADIOACTIVE MATERIALS DISPOSAL
AND MANAGEMENT

COURSE 21

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

COURSE 21 RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

MODULE 21-1 Radioactive Waste Disposal Procedures

MODULE 21-2 Routine Sampling of Radioactive Waste

MODULE 21-3 Radioactive Waste Disposal Regulations

MODULE 21-4 Measurement of External Radioactive Contamination

MODULE 21-5 Regulations for Transportation of Radioactive Materials

MODULE 21-6 Packaging and Monitoring of Radioactive Materials for Shipment

MODULE 21-7 Leak Tests of Sealed Radioactive Sources

Copyright© 1980

Center for Occupational Research and Development, Incorporated
4800 Lakewood Drive, Waco, Texas 76710

Reproduction or publication of the content in any manner, without the express permission of the Center for Occupational Research and Development, Incorporated, is prohibited. No liability is assumed with respect to the use of the information herein.

INTRODUCTION

Radioactive wastes are generated in practically every phase of the nuclear industry, from uranium mining to the use of specific isotopes in research, industry, and medicine. The quantity, activity, and toxicity of these radioactive wastes vary over a wide range. Wastes consist of solids, liquids, or gases, or any combination of these physical forms.

Regulations of the Nuclear Regulatory Commission and the user's license specify waste type, amount, and method of disposal. General methods of disposal are (1) dilution of gas or liquid waste in large volumes of air or water, (2) controlled storage of solid or liquid waste in limited-access areas, and (3) uncontrolled storage in the ground or sea.

Treatment of radioactive wastes varies, depending upon the type of material and the intended method of disposal. Some radicisotopes decay rapidly, and some require a rather lengthy period of time to decay to a safe level. Natural decay is the only way in which radioactivity can be removed from a radioisotope; therefore, whatever is done to a radioisotope, decay ultimately is considered to be the final method of disposal.

MODULE PREREQUISITES

The student should have completed Course 1, "Radiation Physics"; Course 2, "Radiation Protection I"; Course 11,

"Radiation Detection and Measurement"; and Course 12, "Reactor Physics."

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Define the following terms:
   - Low-level liquid waste.
   - Intermediate-level liquid waste.
   - High-level liquid waste.
   - Low-level solid waste.
   - High-level solid waste.
   - Natural radioactivity.
   - Fission products.
   - Activation products.
   - Radioactive gases.
   - Concentration and containment.
   - Dilution and dispersion.
   - Compaction.
   - Engineered storage.
2. Identify the typical types and quantities of radioactive wastes generated at various types of nuclear facilities.
3. Summarize the regulatory requirement, and give an example of a method of compliance necessary to minimize the hazard of a waste disposal.
4. Write a procedure for waste disposal, listing specific problems involved, when given an example of a solid, liquid, or a gaseous radioactive waste.

5. Prepare a flow diagram of general methods of radioactive waste handling and treatment.

THE NATURE OF RADIOACTIVE WASTES

Many different types of radioactive waste products are produced by the nuclear industry. Nuclear Regulatory Commission (NRC) licenses and regulations are specific for each of the over 900 different radioisotopes. Waste products containing these radioisotopes may be soluble or insoluble solids, liquids, or gases; may decay rapidly or slowly; and may give off different types of radiations at various energy levels. Thus, the management of radioactive wastes embraces not only the usual aspects of waste management, but also almost the entire field of the atomic and nuclear sciences.

The principal hazards of radioactive wastes stem from radioactivity. The radiation usually cannot be detected by the senses, and the cumulative effects may not be evident for some time. Fortunately, radioactive emanations may be detected, both quantitatively and qualitatively, with the proper instruments. The radiations may be particulate or electromagnetic. The penetration range of these radiations varies, depending upon the type and energy of the radiation; and some types of radiation require large amounts of shielding material.

Radioisotopes are not influenced by outside actions. Each radioisotope decays according to its own half-life, regardless of its chemical or physical environment. Therefore, the only method of removing radioactivity from an isotope is by allowing it to decay. All processing, storing, and use of radioisotopes must be considered as intermediate steps that lead, finally, to their disposal by decay.

RADIOACTIVITY LEVEL CLASSIFICATION

Practically all areas of the nuclear industry generate radioactive waste products, and these products accumulate as solids, liquids, or gases at various levels of radioactive intensity. Radioactive liquid wastes usually are identified as being one of three levels of activity, and solid materials normally receive only two levels of classifications.

LIQUID CLASSIFICATIONS

Low-level liquid wastes are those that have a radioactive content sufficiently low to allow discharge to the environment with reasonable dilution or relatively simple processing. This type of waste results from either the handling of low-specific-activity materials or from the handling of high-specific-activity materials in a manner that allows small quantities to escape. To be considered a low-level material, the waste must contain no more than 1,000 times the concentration considered safe for direct release into the environment. The concentration contained in the liquid then usually would be less than a microcurie of radioactive material per gallon.

Intermediate-level liquid wastes are liquids that contain too high a concentration of radioactive materials to permit release into the environment after simple dilution. These products must be treated to produce a low-level liquid waste and a high-level waste concentrate. The concentration contained in intermediate-level wastes is approximately 100

to 1,000 times greater than that of low-level material. Such liquids may contain up to 1 curie of radioactivity per gallon.

High-level liquid wastes are those that require special isolation from the environment. High-level liquid wastes contain more than 1 curie of radioactivity per gallon of liquid and may contain up to several thousand curies per gallon. The principal source of high-level liquid waste is the effluent produced by the chemical reprocessing of irradiated nuclear fuel elements. The NRC defines high-level liquid waste material in Title 10, Code of Federal Regulations, Part 50. Officially, it is the aqueous waste that results from the operation of the first-cycle solvent extraction system or the radioactive concentration equivalent, and the concentrated waste from subsequent extraction cycles or equivalent, in a facility for the reprocessing of irradiated reactor fuel. Because of this definition, all other waste, regardless of its origin, falls into the category of other than high-level and may be disposed of in a commercial land-burial facility. There is a requirement, however, that the waste be converted to a solid form for burial at a commercial radioactive waste disposal facility. NRC regulations require that high-level wastes be buried in a federal repository. Additionally, some high-level liquids may require special cooling to prevent self-boiling.

SOLID WASTE ACTIVITY CLASSIFICATION

The application of the terms "high-level" and "low-level" to solid waste is somewhat different from the use of these terms to describe liquids because the concept of

Maximum Permissible Concentration (MPC) of radioactive materials in the environment does not apply directly to solids. At commercial burial sites, the term "low-level" alludes to the hazard potential of the buried radioactive material and indicates that there is little likelihood of the material being dispersed in the environment.

High-level solid radioactive wastes fall into two distinct categories: those in which the concentration of the radioactive materials is so great that there is a heat dissipation problem, and those that do not have a heat problem. High-heat, high-level solid wastes usually require external cooling in order to prevent their melting and/or burning. Low-heat wastes contain enough radionuclides to require prevention from release into the environment but are dilute enough that there are no problems with the removal of heat.

GASEOUS WASTES

Low-level gaseous wastes are, generally, those whose concentration level is considered to be safe for discharge into the environment. Anything other than low-level gaseous products is trapped either chemically or cryogenically and treated as a solid or liquid waste.

SOURCES OF RADIOACTIVE WASTE

All places at which radioactive materials are used are potential sources of radioactive wastes; however, the greatest source of radioactive waste products is the nuclear fuel cycle. This cycle includes wastes that contain natural radio-

activity as the result of mining, milling, and preparation of fuel for reactors and cores for weapons. Reactor operation and the subsequent processing of irradiated fuel elements produce wastes rich in fission products. Likewise, the irradiation of nonfuel materials in and around reactors produces additional radioactive wastes. Table 21-1-1 lists the types and sources of wastes in the nuclear fuel cycle and contains brief statements about general waste disposal methods.

Natural radioactivity refers to the radioactive materials found in nature. The natural radioactivity in the fuel cycle includes uranium, thorium, and their natural decay products. Wastes from the mining, ore milling, and fuel fabrication by use of uranium and thorium will contain uranium, thorium, radon, radium, and other naturally-occurring radioisotopes.

Most uranium mine operations are in dry formations, although some require continuous pumping of large quantities of water to keep them from flooding. This water contains only trace quantities of radioactivity and presents no significant health hazard. Recently, however, a mining method for uranium, involving the leaching of ore from a subterranean deposit by high-pressure water injection, has been used. The untreated waters from this type of operation are a health problem and must be considered a radioactive waste.

Uranium ore concentrating mills discharge liquid wastes into ponds or lagoons at the rate of 300 to 500 gallons per minute per 1,000 tons of ore processed per day. The solid residue from this operation, called "tailings," contains an insoluble form of radium.

Chemical purification of the ore concentrates is the next step in the fuel cycle and results in a "feed" prepa-

TABLE 21-1-1

TYPES AND SOURCES OF NUCLEAR FUEL CYCLE WASTES

Type of waste radioactivity	Source of waste	Form of waste	Typical isotopes	Type of radiation	Disposal methods
Natural activity	Mining of Uranium ores	Solids	Uranium-238	α,γ	Pile in open
		Liquids	Thorium-230	α,γ	Seep into ground
		Gases and dusts	Radon-222	α	Ventilate mine
	Fuel fabrication plants	Solids	Uranium-238 Uranium-235	α,γ	Decontaminate
		Liquids (acids)	Uranium-238 Uranium-235	α,γ	Neutralize, concentrate, and bury residue
		Dusts	Uranium-238 Uranium-235	α,γ	Ventilate, filter, and disperse to air
Fission-product activity	Fuel irradiation and processing	Solids (from purposeful solidification)	Strontium-90 Cesium-137	β β,γ	Encase in container and store permanently (600 years)
		Liquids (with strontium cesium removed)	Technetium-99 Ruthenium-103 Cerium-144	β β,γ β,γ	Store in tanks for several years; then solidify in place
		Gases	Iodine-131	β,γ	React with chemicals to bind in solid, e.g., silver iodide
			Krypton-85	β,γ	Disperse to air
Activation-product activity	Reactor materials unavoidably irraidated during operation	Solids	Aluminum-28 Manganese-56	β,γ β,γ	Package and ship for land burial
		Liquids (dissolved materials)	Cobalt-58	β^+,γ	Evaporation or ion-exchange; bury residue
		Gases	Nitrogen-16	β,γ	Hold for decay (very short life) then disperse to air
	Purposeful irradiation to produce useful isotopes	Solids	Cobalt-60	β,γ	Ship for burial when no longer useful (long life)
			Phosphorus-32	β	Store for decay to safe levels (short life)

ration. "Feed" is used as uranium salt for isotope separation, or it is converted into metallic uranium or uranium oxide for fuel elements. Each ton of uranium ore processed produces approximately 1,000 gallons of low-level liquid waste.

Fabrication of fuel elements from purified uranium produces wastes of very low level, because the highly-active daughter products have been removed. Long-term storage of these materials, however, will show an increase in activity caused by a buildup of decay products. Fabrication of fuel elements also produces contaminated scrap as a waste material.

Fission products are produced when fissionable materials are irradiated with neutrons and are the largest source of radioactive waste, by far, in terms of contained radioactivity. The fission or splitting of each fissionable atom results in two new atoms called "fission products." The combined mass of these two new atoms is almost equal to that of the original atom. Fission products are radioactive and undergo one or more steps of radioactive decay before becoming stable. In some, this decay may be a matter of seconds; in others, thousands of years may be required.

Fission products are created in the nuclear fuel and remain in the fuel assemblies until they are reprocessed. Fuel assemblies of light-water reactors (LWR's) – the type in general use – are bundles of metal tubes, containing cylindrical pellets of uranium dioxide. Each pellet is approximately 1/2 inch in length, by 1/2 inch in diameter. Fissionable fuel material, as well as the fission products, thus are contained within these pellets. These fission products absorb neutrons needed in the chain reaction; therefore, they must be removed, or they would eventually

cause the chain reaction to cease. A spent fuel element still contains much valuable fissionable material, even after it has been used for a considerable time. Recovery of this fissionable material is important, along with removal of the fission products, and is an important economic aspect of the nuclear industry.

The spent fuel elements are transported to a fuel reprocessing center, where the fissionable material is reclaimed by solvent extraction. The fuel elements first are reduced mechanically to small pieces and then dissolved in nitric acid. The fissionable materials then are extracted from the solution by an organic solvent. Practically all the fission products remain in the water/acid phase. The waste material then can be collected, concentrated, and disposed of as high-level waste. Approximately 99.9 percent of the fissionable fuel may be reclaimed in this process. Each kilogram of processed fuel produces approximately 100 gallons of highly radioactive liquid. Estimates are that this process will produce 3 million gallons of waste per year by the end of the century.

Activation products are materials made radioactive by the neutron irradiation of nonfuel materials in a nuclear reactor. Structural materials are activated, as are impurities in the coolant (water, in most cases) and even in the coolant itself. Traces of iron and nickel dissolved in the coolant, for example, will become radioactive when exposed to the neutron flux of an operating reactor. These radioactive materials may be removed by ion exchange or by other methods.

RADIOACTIVE GASES

Both types of commercial nuclear power plants currently in use in the United States – the boiling-water reactor (BWR) and the pressurized-water reactor (PWR) – produce radioactive gases. Radioactive gases result from the activation of such materials as oxygen, nitrogen, and argon, and from the release of gaseous fission products such as krypton, xenon, and iodine. The fission products leak from the fuel elements into the primary reactor coolant stream. Naturally, the amount of fission products in the coolant water depends on the integrity of the fuel elements themselves. As long as the metal cladding that covers the fuel material is intact, the gas cannot escape; however, as the reactor operates, the cladding material around the fuel may develop pinhole leaks, thereby releasing some radioactive gases.

Most plants are designed to operate with fuel-element leakage of up to one percent. Such leakage then dictates the design of systems to handle the radioactive gases and to maintain discharges into the environment within the established limits.

The gases released into the primary coolant of the BWR's are carried to the turbines and condensers, along with the steam produced by boiling. The steam is condensed back to water in the condenser; but the noncondensable gases, including a small volume of radioactive gases, are vented to a cleanup system, which provides a holding time for radioactive decay. With current technology, the gases are filtered, held for a time, and then released through a stack into the environment.

PWR systems differ from BWR systems, in that most of the gases remain in the reactor coolant water in a sealed system during normal operation. The water in this system is not permitted to boil. During reactor shutdown for maintenance or refueling, the temperature and pressures are lowered, and the gases are vented to a cleanup system for containment and controlled release into the atmosphere. A small amount of gas products is discharged continuously during operation.

The gaseous products from both types of reactors are short-lived and rapidly decay to nonradioactive matter.

OTHER SOURCES OF RADIOACTIVE WASTES

Radioactive wastes also are generated by the multitude of businesses that use radioisotopes in their daily operations. Such businesses include commercial laboratories, hospitals, universities, and all types of industry. The wastes from these operations may be at almost any level of activity and may consist of any type of material. The waste from each establishment must have special consideration for handling and disposal.

MANAGEMENT OF RADIOACTIVE WASTE

The effective management of radioactive waste products includes all the steps necessary for the safe disposal of the radioactive material and the control and direction of these steps. Specific procedures are required for each

type of waste. Fortunately, two general procedures, rather broadly applied, are used throughout the industry.

The first procedure is concentration and containment, and it is used extensively. This method is popular because radioactive materials can be stored safely in controlled-access areas, but the volume of the material must be reduced to prevent unnecessary loss of space.

The second concept is dilution and dispersal. This procedure may be applied to certain low-level wastes for which dilution will reduce the activity below the permissible levels for discharge into the environment. It must be remembered that whenever radioactive materials are to be released into the environment, the amount of material is determined quantitatively for each specific isotope and that all discharges must be controlled.

Application of these broad concepts requires that each case be evaluated individually and that the results be monitored thoroughly. The continued conscientious reexamination of these procedures will assure safety and economy in the problems of radioactive waste disposal.

LIQUID WASTE TREATMENT AND DISPOSAL

CONCENTRATION AND CONTAINMENT

The concept of concentration and containment is applied to all levels of liquid radioactive wastes. The procedures used in concentration are both chemical and physical, and they apply to a variety of practices. These practices combine to produce a high-level radioactive concentrate that

is contained and a low-level effluent that may be treated further or simply diluted before discharge.

Chemical Methods

Liquid radioactive waste is treated chemically to extract material into a solvent for reclamation, for precipitation of material for concentration, for ease of separation, or for the removal of useful materials. Ion exchange, sometimes called a "filtration process," actually is a chemical method of separation. Regardless of the method, the ultimate goal of chemical treatment is the concentration of the radioactivity in a solid or sludge, leaving a relatively low-level of activity in the original liquid.

Physical Methods

Physical methods of treating radioactive liquid wastes include filtration, freezing, decantation, and evaporation. These methods frequently are in combination with some chemical treatment, but may be used independently for specific applications.

Filtration usually is employed after some chemical pretreatment. Simple filtration may be accomplished, however, through activated charcoal or some other highly adsorbent material. Filtration is very effective, particularly if the material has been flocculated (caused to form large particles) before filtration.

Freezing may be used to produce a slurry of highly radioactive material, with subsequent physical methods used

to remove the radioactive fraction, although this method has found only limited use.

Decantation is used after allowing the particulate material suspended in a liquid to settle to the bottom of a container. This method, while being less costly than filtration, requires considerably more time, unless the rate of settling can be increased chemically.

Evaporation, or distillation, is one of the most effective means of removing radioactive wastes from a liquid. In the past, however, this method normally has been limited to large treatment centers because of economics. Presently, there are several small packaged units for low-temperature evaporation that have become commercially available. These units are intended for the treatment of relatively small batches of low-level liquid wastes and should be of interest to small installations.

Figure 21-1-1 is a flow chart for a typical low-temperature vacuum evaporator. The radioactive liquid waste is concentrated by use of a low-temperature-high-vacuum evaporation process. After the desired concentration is achieved, the residual wastes are transferred to a storage system or to a solidification system for ultimate disposal. The radioactivity in the effluent may be expected to be up to 100,000 times less than that in the waste that feeds into the system.

The principal features of this system are:

- Low-temperature operation.
- Efficient multiple system of separators.
- Automatic purity control.
- Automatic self-cleaning during shutdown.

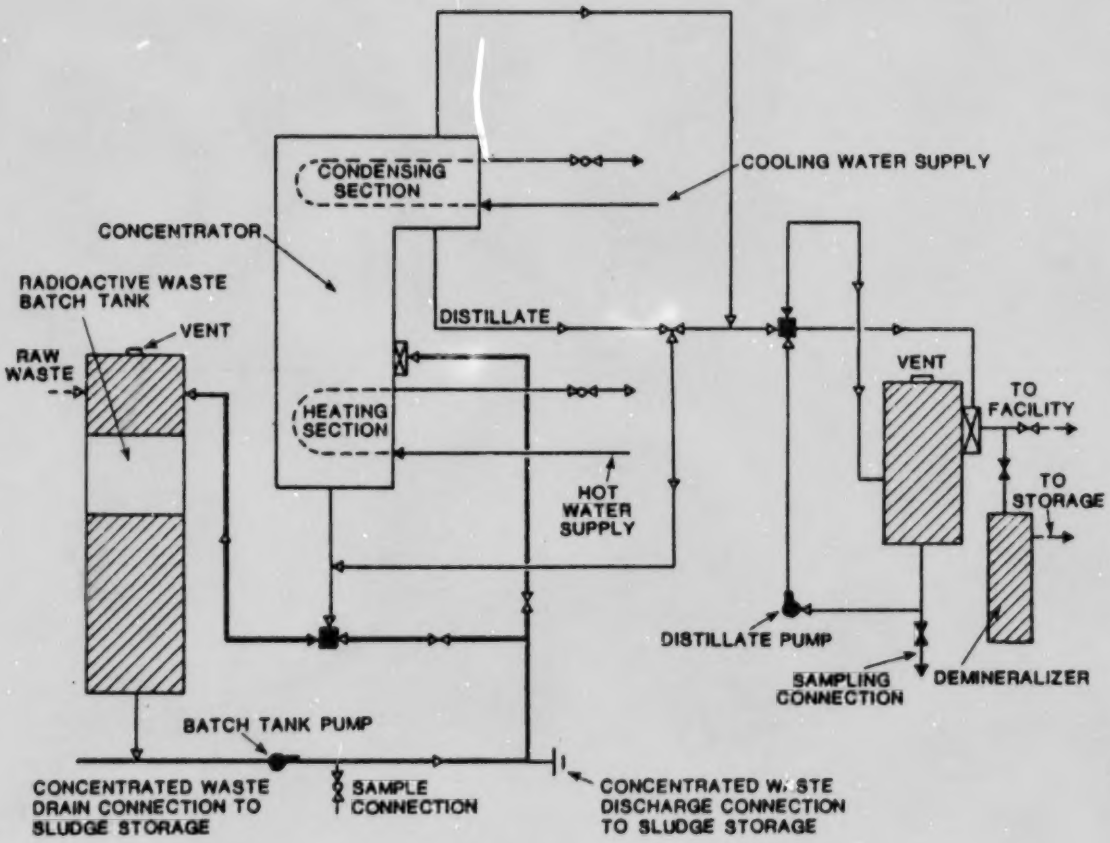


Figure 21-1-1. Low-temperature evaporation system.

Specific operations vary from unit to unit, but the fundamentals remain the same. These units are based upon the boiling of the solution at reduced pressure and temperature in order to remove the solvent. Similar units are operated throughout industry to clean and dewater petroleum products and cleaning solvents.

Solidification

The semi-solid residue from radioactive liquid waste may be treated by one of two methods. It simply may be dewatered and dried before storage, or it may be mixed with cement to form a solid. Either material usually is sealed in a steel canister before ultimate disposal.

DILUTION AND DISPERSION

Low-level liquid wastes and the effluent from the treatment of both high- and intermediate-level liquid wastes may be disposed of by dilution and dispersion. Within the United States, Title 10, Code of Federal Regulations, Part 20, spells out the requirements for discharge of any radioactive material into the environment. Regulation 10CFR20 requires that (1) the material must be readily soluble or dispersible in water; and that (2) the quantity of any licensed or other radioactive material released into the system in any one day does not exceed either (a) the quantity, which, if diluted by the average daily quantity of sewage released into the sewer by the installation, will result in an average concentration equal to the Maximum Permissible Concentration (MPC) specified in Appendix B, Table I, Column 2 of 10CFR20, or (b) ten times the quantity of such material specified in Appendix C of 10CFR20, whichever is the larger amount. Regulation 10CFR20 further specifies that the quantity of any radioactive material released in any one month, if diluted by the average monthly quantity of water released by the installation, must not

result in an average concentration exceeding the 40-hour occupational MPC's and that the gross quantity of radioactive material released into the sanitary system by the installation must not exceed 1 Ci/yr. The following examples illustrate the calculations required when disposing of radioactive waste material in the sanitary waste-water system under the above regulations. Refer to Appendices B and C of 10CFR20 to obtain the required MPC's.

EXAMPLE	
Given:	A quantity of the radioisotope ^{131}I is to be discharged into the sanitary waste-water system. Case A, waste-water discharge is 15,000 liters per day. Case B, waste-water discharge is 1,000 liters per day. ^{131}I MPC_w from Table 1, Column 2, Appendix B, 10CFR20: 6×10^{-5} µCi/ml ^{131}I MPC from Appendix C, 10CFR20: 10 µCi/ml
Find:	The quantity of ^{131}I that may be discharged under each case.
Solution:	Case A: Appendix B 6×10^{-5} µCi/ml x 10^3 ml/l x 1.5×10^4 l/d = 900 µCi/d Appendix C 10 µCi/ml x 10 = 100 µCi/d

Therefore, the installation could dispose of up to 900 µCi of ^{131}I per day.

Case B:
Appendix B
6×10^{-5} µCi/ml x 10^3 ml/l x 10^3 l/d = 60 µCi/d
Appendix C
10 µCi/d x 10 = 100 µCi/d
Under these conditions the installation could dispose of up to 100 µCi per day.

There is a further restriction, however, that the monthly discharge must not exceed the MPC_w when diluted with the average monthly flow of waste water. The institution in Case B would be limited to 1800 µCi/month rather than the 3000 µCi that could be discharged if the installation disposed of the maximum allowed under Appendix C for Case B every day.

An additional limitation is applied when combinations of radioisotopes are involved. The limit for the combination is calculated by establishing the ratio between the amount of the isotope present and the amount permitted for that isotope alone. The sum of the ratios for all the isotopes in the combination may not exceed "1."

Regulation 10CFR20 specifically exempts the excreta from people being treated with radioisotopes for medical diagnosis or therapy from regulation. This amount of radioactivity is not used, therefore, in the calculation of discharge amounts.

TREATMENT AND DISPOSAL

Radioactive solid wastes are classified as low-level or as high-level wastes. Both classifications may receive the same general treatment before burial. These treatments are designed to reduce the total volume of the material before burial.

COMPACTION

The most favored method of volume reduction of solids has often been compaction, because of the commercial availability of reliable, easily operated equipment. This, coupled with the ease and low cost of burial of simple packages has generally diminished the economic incentives of reducing stored solid waste volumes.

The requirements for compaction must specify limitations on the material as to its composition, moisture, containment, volume, and isotopic content. Materials suitable for compaction frequently include such things as paper, cloth, rubber, plastic, wood, glass, and light-gauge metal objects. Objects that are large or solid are best excluded because they usually are not compressible. Likewise, objects with a high moisture content should be avoided because of limited compressibility or the possible spread of contamination by leakage during compression. Explosive, corrosive, and pyrophoric materials also should be avoided.

The most common compactor in use in the nuclear industry is the 55-gallon drum compactor. Such a unit can be operated either mechanically or hydraulically to produce a final product encased in a 55-gallon steel drum. Figure 21-1-2 is a representation of a high-compression drum compactor. Such compactors are covered by protective enclosures that prevent the escape of airborne particulates.

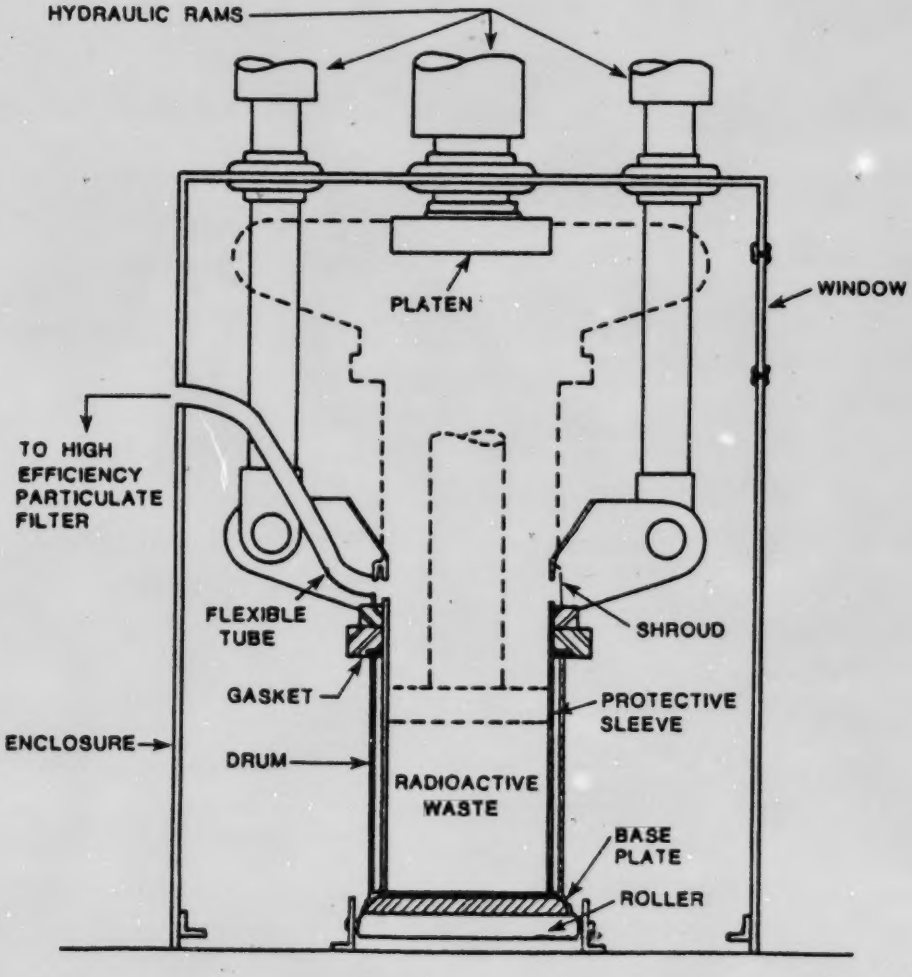


Figure 21-1-2. High-compression drum compactor.

Since the compactor presses the material directly into a drum, the waste material is contained in a final leakproof container.

INCINERATION

The use of incineration as a method of volume reduction has met only with limited success in the United States. Several systems have been tested using combustible trash contaminated with radioactive materials, but almost all of them have failed to provide the desired performance and have been too expensive to maintain. Thus far, the principal use of incineration has been in the recovery of plutonium from burnable scrap.

BURIAL

Disposal of low-level, solid, radioactive waste presently is accomplished best by near-surface land burial. The term "low-level" refers to the hazard potential of the radioactive material to be buried at a commercial burial site. Regulation 10CFR20 specifies that the waste must be in solid form and that the commercial land burial facilities must be on land owned by either a state or the Federal government. Figure 21-1-3 is a map that identifies the commercial land burial sites for low-level wastes at Federal facilities. Additionally, the Agreement discusses license facilities on state property.

Figure 21-1-3. Commercial burial sites in the United States.

High-level solid wastes presently are being handled through a concept known as "engineered storage" at repositories called "Retrievable Surface Storage Facilities." These facilities will be equipped to water-cool the storage canisters. Figure 21-1-4 is an illustration of a typical Retrievable Surface Storage Facility. The canisters to be stored at the facilities are from 1/2 foot to 2 feet in diameter and from 2 to 10 feet in length.

A typical storage canister is depicted in Figure 21-1-5. The filled canisters are shipped to the facilities in special shipping casks designed to provide both cooling and radiation shielding during transit. Figure 21-1-6 illustrates a typical shipping cask for spent fuel. The

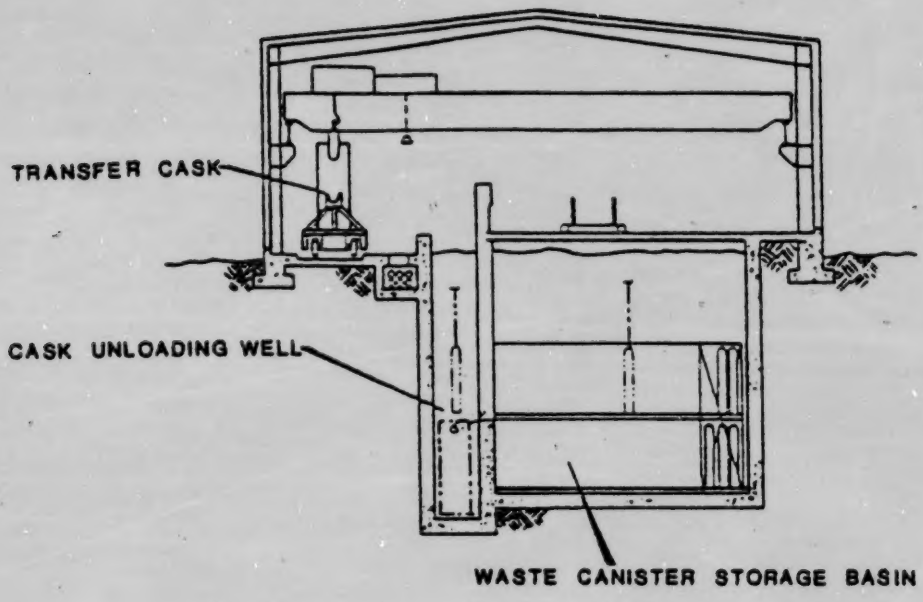


Figure 21-1-4. Retrievable surface storage facility.

	DIAMETER	LENGTH
RANGE	6" TO 24"	2' TO 10'
TYPICAL	12"	10'

Figure 21-1-5. Typical storage canister.

larger cask can hold up to 12 canisters and when full weighs about 100 tons. Smaller casks are used to transport a single canister at a time. The amount of heat produced by each storage canister varies from 2 to 5 kilowatts; therefore, constant cooling is required.

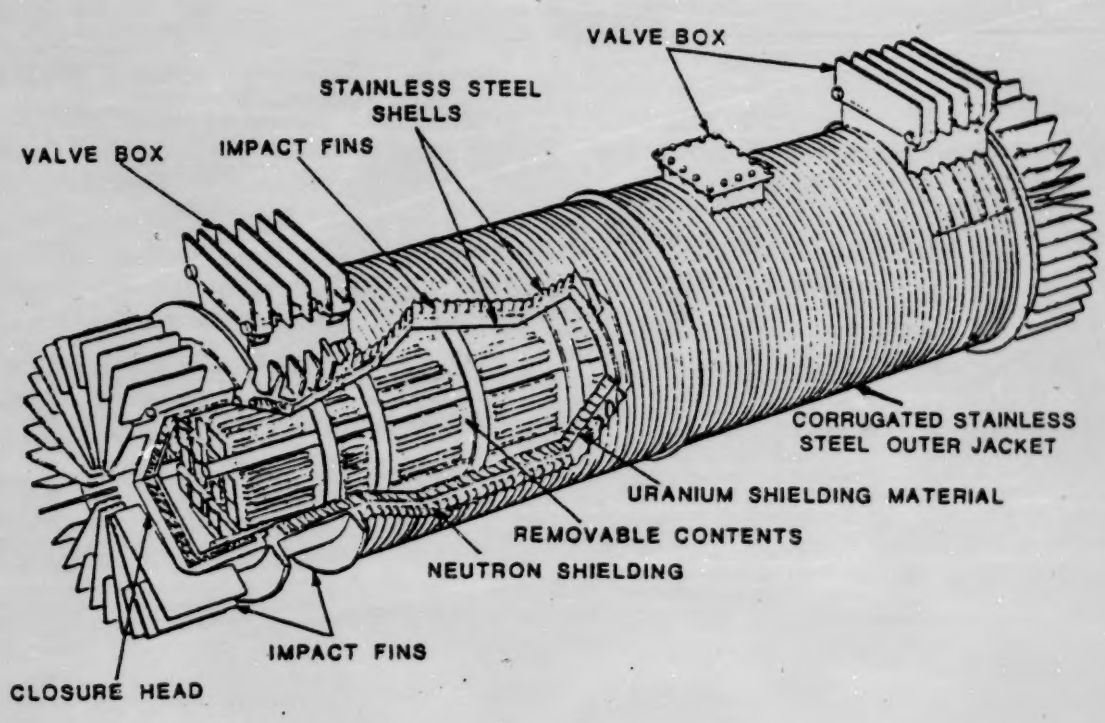


Figure 21-1-6. A typical spent-fuel shipping cask.

Salt-dome storage is another method of high-level solid-waste disposal; it involves the same procedures and canisters as already discussed. Although there are serious questions regarding the environmental impact of this approach, burial in salt domes does offer a recognizable, potential for the safe disposal of radioactive waste.

Other methods of disposal are proposed, but one promising suggestion is the utilization of the heat generated by the storage canister. Under this plan, the 2 to 5 kilowatts of heat produced by each storage canister would be used to power small generating stations to provide a source of needed energy.

TREATMENT AND DISPOSAL OF GASEOUS WASTES

Gaseous wastes, which consist of either true gases or particulate matter, require some special considerations. Specialized structures are required for the containment and treatment of these materials.

Airborne particulates may be removed by settling chambers, cyclones, impingement separators, scrubbers, or filtration devices. The residue from these types of removers can be handled as either solid or liquid wastes.

REMOVAL OF NONPARTICULATE ACTIVITY

Filtration and other methods of particulate removal are not effective in removing materials such as the radioactive noble gases, halogens, and the volatile compounds of ruthenium and polonium. Removal methods for these materials include adsorption, low-temperature trapping, and chemical reaction.

Ruthenium readily is recovered in a trap packed with iron, and iodine can be trapped in activated charcoal or on silver. Noble gases and halogens can be removed by adsorption on charcoal at low temperatures. These waste ma-

terials then can be treated as solid wastes, can be allowed to decay to stability, or can be desorbed, diluted, and dispersed into the atmosphere.

A WASTE MANAGEMENT SYSTEM

A complete waste management system includes all the procedures involved from the time the waste material is produced until it is discharged into the environment and until the environment is surveyed to assure safety. Figure 21-1-7 is a flow chart of a typical waste management system.

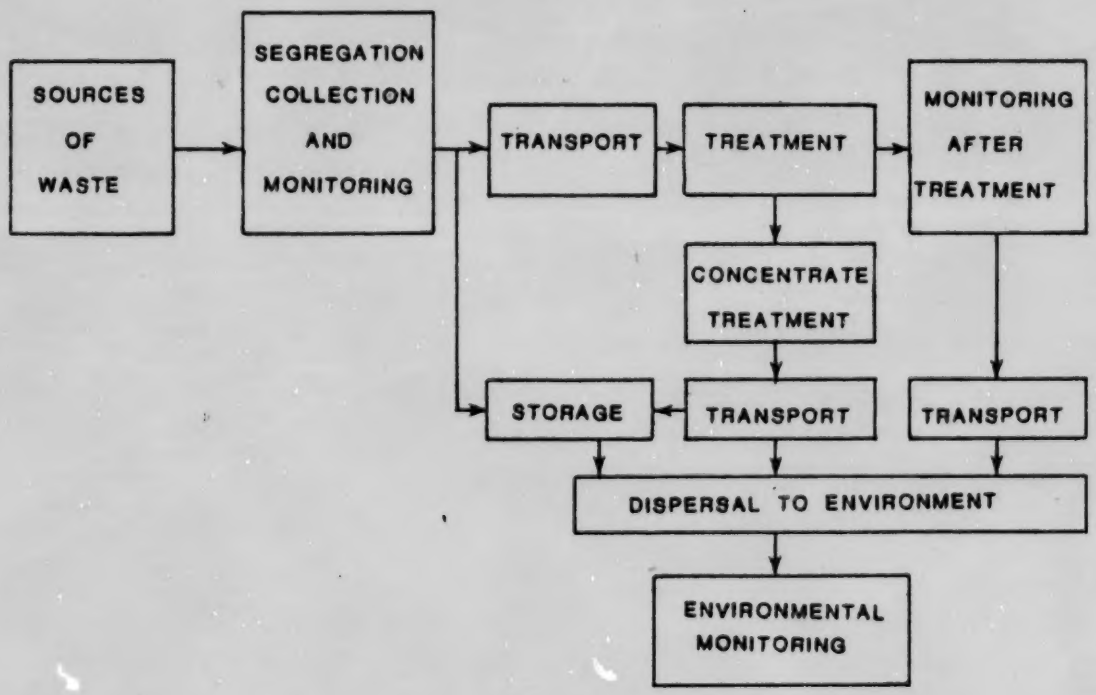


Figure 21-1-7. A typical waste management system.

This chart does not necessarily apply to all sites and operations; and for some systems, a different arrangement of the elements may be necessary, although the essential elements are present here. It is important to note the requirement for monitoring before and after treatment, and also after dispersion into the environment.

EXERCISES

1. Identify the appropriate section of 10CFR20 that limits to less than 1 curie per year the discharge of radioactive waste to a sewer system.
2. Assume a facility produced liquid low-level waste in which the ^{137}Cs concentration was 40 times higher than the ^{90}Sr concentration. This waste would be diluted enough that the resulting concentration is within legal limits. What other restrictions are placed upon this dilution and disposal into a sewer system?
3. What is the maximum quantity of Radium-226 and of Plutonium-239 allowed for disposal into a sewer system?
4. A batch of liquid waste with a total volume of 100 liters is to be disposed into a sewer system. Analysis of the material lists its contents as 10 millicuries of ^{131}I, 0.1 millicuries of ^{90}Sr, and 10 millicuries of natural thorium. The waste-water flow from the sewer system of this facility is 1,000 liters per day. How much of the liquid waste could be discharged each day?

MATERIALS

Geiger-Mueller Counter
Uranyl nitrate.
Sodium carbonate.
Ferric chloride.
Hydrochloric acid.
Funnel.
Filter paper.
Wash bottle.
Hot plate.
400-ml beakers.
Distilled water.

PROCEDURES

SEPARATION OF URANIUM FROM ITS DECAY PRODUCTS

Explanation: Uranium can be separated from its decay products by holding the uranium in solution as a carbonate complex while coprecipitating the daughter products with ferric hydroxide.

1. Dissolve 20 grams of sodium carbonate in 200 ml of hot distilled water.
2. Add 5 grams of uranyl nitrate hexahydrate, and stir until completely dissolved.
3. Add 5 ml of 1% ferric chloride in water and stir.
4. Allow to stand for 2 minutes.
5. Filter through a loose-textured filter paper.

6. Wash the residue twice with 10-ml portions of distilled water, saving all the filtrate and washings.
7. Evaporate the filtrate and washings to dryness, being careful not to splatter contamination.
8. Dissolve the iron hydroxide residue on the filter paper by pouring 3 normal hydrochloric acid through the filter paper until all the precipitate is removed.
9. Evaporate the resulting solution to dryness.
10. Count each of these residues with the G-M counter, and count another 5-gram sample of uranyl nitrate hexahydrate. Record data in Data Table 21-1-1.
11. Discuss results.

DATA TABLE 21-1-1

Material	Sample cpm	Background cpm	Corrected cpm
Uranium filtrate			
Dissolved residue			
Unused uranyl nitrate			

REFERENCE MATERIALS

Amphlett, C. B. Treatment and Disposal of Radioactive Wastes. New York: Pergamon Press, 1961.

Gilmore, William R., ed. Radioactive Waste Disposal, Low and High Level. Park Ridge, NJ: Noyes Data Corporation, 1977.

Glueckauf, E., ed. Atomic Energy Waste, Its Nature, Uses and Disposal. New York: Wiley-Interscience, 1961.

International Atomic Energy Association (IAEA), Safety Series #19. The Management of Radioactive Wastes Produced by Radioisotope Users.

IAEA Safety Series #24. Basic Factors for the Treatment and Disposal of Radioactive Wastes.

Title 10, Code of Federal Regulations, Part 20.

TEST

1. Define the following terms:

   Low-level liquid waste.

   Intermediate-level liquid waste.

   High-level liquid waste.

   Low-level solid waste.

   High-level solid waste.

   Natural radioactivity.

   Fission products.

Activation products.

Radioactive gases.

Concentration and containment.

Dilution and dispersion.

Compaction.

Engineered storage.

2. What type of radioactive waste material might be expected from a spent reactor fuel reprocessing station?

3. Assume that a chemical purification system processes 17 tons of uranium to produce "feed." Is the liquid waste from this operation low- or high-level activity? What would be the expected volume from this operation?

4. Write a summarization of the regulations concerning the disposal of a liquid waste containing microcurie quantities of ^{131}I, ^{32}P, ^{65}Zn, and ^{124}Sb.

5. Write the procedure for the proper disposal of 7 millicuries of ^{210}Pb dissolved in 22 liters of water.

6. Sketch a flow diagram for the general methods of handling and treatment of radioactive waste from a source that produces solid and liquid wastes in curie quantities per day and gaseous wastes in microcurie quantities.

NUCLEAR TECHNOLOGY

MODULE 21-2

ROUTINE SAMPLING OF RADIOACTIVE WASTE

RADIOACTIVE MATERIALS DISPOSAL
AND MANAGEMENT

COURSE 21

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

COURSE 21 RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

MODULE 21-1 Radioactive Waste Disposal Procedures

MODULE 21-2 Routine Sampling of Radioactive Waste

MODULE 21-3 Radioactive Waste Disposal Regulations

MODULE 21-4 Measurement of External Radioactive Contamination

MODULE 21-5 Regulations for Transportation of Radioactive Materials

MODULE 21-6 Packaging and Monitoring of Radioactive Materials for Shipment

MODULE 21-7 Leak Tests of Sealed Radioactive Sources

Copyright© 1980

Center for Occupational Research and Development, Incorporated
4800 Lakewood Drive, Waco, Texas 76710

Reproduction or publication of the content in any manner, without the express permission of the Center for Occupational Research and Development, Incorporated, is prohibited. No liability is assumed with respect to the use of the information herein.

INTRODUCTION

Radioactive wastes present special problems to the technician; however, the majority of these problems usually are solved with relative ease, once the various requirements are known. Wastes must be sampled in order that the materials in them can be identified. Proper handling and treatment of samples will provide the needed information without exposing the involved personnel to conditions that could be hazardous to their health.

MODULE PREREQUISITES

The student should have completed Module 21-1 and a course in basic algebra.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Identify the inherent chemical and radiological dangers when given a written description and analysis report of a sample of radioactive waste material.
2. Write a procedure for sampling a solid, liquid, or gaseous radioactive waste.
3. Identify the problems associated with the sampling of air discharged from a nuclear facility.

4. Calculate the activity per unit volume of a radioactive liquid or of a gas.

WHY TAKE SAMPLES?

One of the most important steps in the treatment and disposal of any radioactive waste material is the determination of the composition of the material and the amount of radiation present. This determination, which must be made with as much certainty as possible, can be accomplished only when a representative sample of the material is obtained and subjected to the appropriate tests. The key words here are "representative sample," for if the sample is not representative of the material, then any data obtained from it is almost totally useless. Identification and classification of the waste material are the first steps in the obtaining of a representative sample.

IDENTIFICATION AND CLASSIFICATION OF WASTE MATERIAL

A material becomes waste when it is defined as such, meaning that the material is no longer useful at its present site. The identification of a material as a waste, therefore, simply requires that someone name it as such. Once the material has been identified as waste, the problem of what to do with it arises.

Records that identify the chemical and radioactive content of the material should exist. Regrettably, these records may not provide an accurate representation of the true content.

The radioactive waste material, once identified with whatever records available, must be classified according to

its physical state and radioactive content. Classification of the waste is done by the health physicist after review of the sampling data.

PHYSICAL AND RADIOLOGICAL CLASSIFICATION

Classification by physical state is reasonably simple; that is, it is fairly easy for the technician to determine if a material is a solid, a liquid, or a gas. Classification by radiation content is not quite so simple. Radiologically, wastes usually are classified as either high- or low-level with respect to radiation content. This classification, as mentioned in Module 21-1, is based upon specific content levels.

Low-level solid waste is material that has a relatively low hazard potential after being buried. The concentration of activity within high-level waste material is such that this type of waste must be contained and continuously monitored to prevent escape into the environment.

Low-level liquid waste contains 1 microcurie or less of radioactive material per gallon of solution and usually can be released into the environment with simple dilution. Any greater concentration requires additional treatment. All liquids must be sampled and monitored.

Low-level gaseous wastes are those that may be discharged directly into the environment. Any gaseous waste containing activity concentrations above that which can be released into the atmosphere is considered high-level waste and requires containment. Both of these classes of wastes require sampling and continuous monitoring.

CHEMICAL COMPOSITION

One of the most important reasons for the sampling of waste material is to determine the presence of chemicals. This is necessary, not only to determine the type of container required for the material, but also to determine the type of treatment to be applied to the material. Additionally, the chemistry of the material must be known in order that proper safety procedures can be applied in the treatment of the waste.

SAFETY

The safety considerations for any waste material are important, but for a radioactive waste they become critical. Due to the presence of radioactivity, not only the normal chemical waste material safety considerations must be observed, but the additional considerations for radiation safety as well. The effect of the radiation on the waste material and the container must also be taken into account when the handling of the waste material is planned.

CHEMICAL DANGERS

Identification of the chemical dangers of radioactive wastes is necessary to prevent explosions and/or corrosion of containers. In fact, the chemicals present often are as dangerous as the radioactivity. Such cases present dual safety problems and require that the supervisors and operators be knowledgeable in both chemical safety and radiation protection.

RADIATION DANGERS

Any waste material other than low-level liquids and gases represents a radiation hazard, requiring that the material be shielded and/or handled remotely. Any operation involving hazardous radiation material must be carried out under the supervision of health physics personnel and must be monitored from start to finish.

SAMPLING PROCEDURES

Sampling procedures vary widely, depending upon the type of material to be sampled and the amount of radioactivity present. There is one pervading requirement, however: the sample must be representative of the whole. Because of this requirement, certain standardized sampling procedures have been developed and are in use throughout the industry.

GASEOUS MATERIALS

The release of gaseous and particulate radioactive materials into the atmosphere has increased greatly since the utilization of radioactive materials for domestic and industrial purposes. These releases to the environment can lead to the contamination of air, food, and water consumed by man, and thereby may constitute a health hazard. Figure 21-2-1 illustrates the path of airborne radioactive materials to man. The figure illustrates that air is the greatest environmental media used by man. Table 21-2-1 lists the numeric comparison of air, food, and water used by an average man.

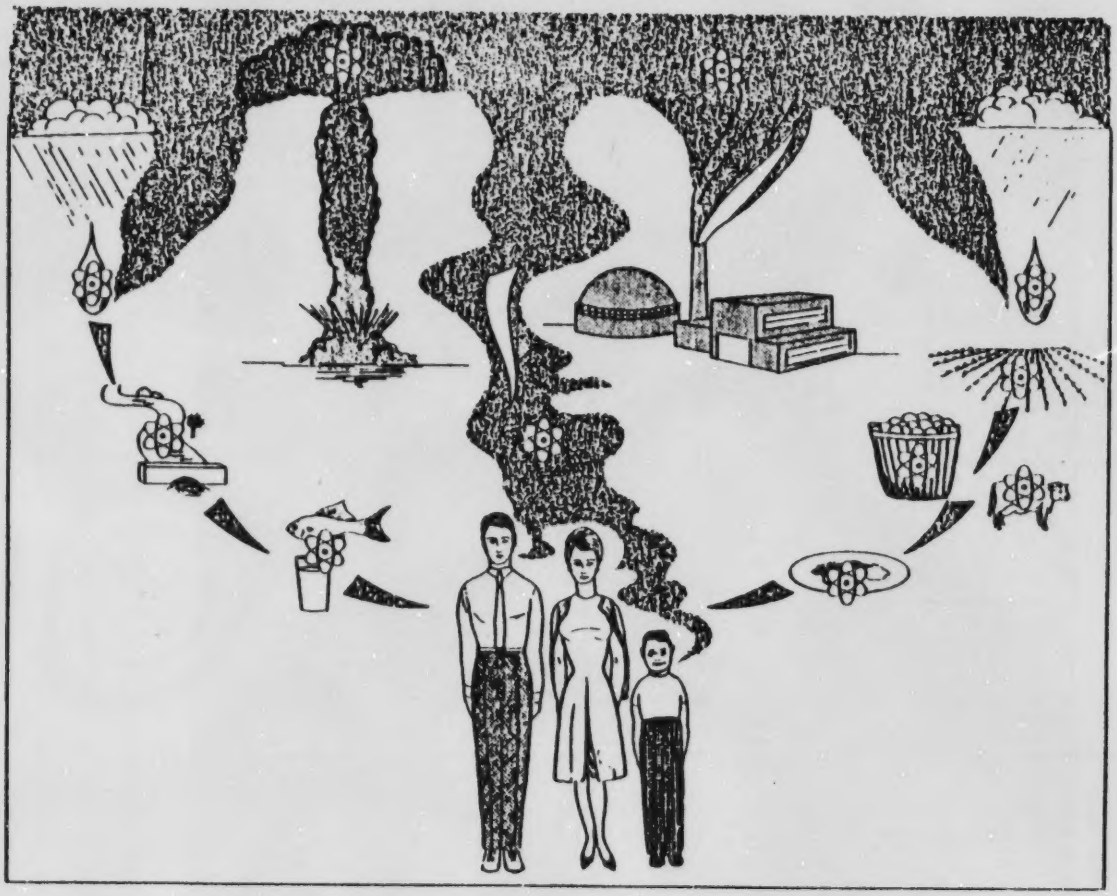


Figure 21-2-1. Radioactive contamination of man from air (air-to-man chain).

TABLE 21-2-1
COMPARATIVE USE OF AIR, FOOD, AND WATER

Media	Volume/Day	Weight/Day
Air	2×10^4 1/day	25.86 kg/day
Food	--	1.86 kg/day
Water	2.2 1/day	2.22 kg/day

The illustration would seem to indicate that the air pathway is the greatest exposure pathway to man; however, such is not necessarily the case. Each radionuclide pathway must be considered individually and compared to the total. The type of radioisotope involved in the contamination also will affect the degree of exposure in any given pathway. For example, ^{32}P is absorbed readily by most plants. This would weight the food chain pathway more heavily than the air pathway in degree of exposure for that particular nuclide.

COMPOSITION OF AIR

Gaseous radioactive waste products are mostly air mixed with radioactive material. The physical composition of radioactive gaseous waste is a mixture of both gaseous and particulate materials – more specifically, of gases and aerosols. An aerosol is a suspension of fine solid or liquid particles in a gaseous medium.

The gases are composed of free molecules of material that constantly are colliding and rebounding. These gas molecules have diameters that range in size from 0.0002 μm to 0.001 μm. The radioactive gaseous products that may be found are ^{131}I, ^{41}A, ^{3}H, ^{14}C, ^{222}Rn, and ^{220}Rn.

The aerosols found in waste gases contain particles as large as approximately 40 μm. Particles larger than 40 μm in diameter tend to settle out due to gravity. Radioactive aerosols may exist in a gas as the radioactive material alone, or as other particles (such as dust particles) with the radioactive material attached to them. Likewise, the radioactive material may exchange alternately between gas and aerosol. Table 21-2-2 lists a general classification of aerosols. The radioactive content of an aerosol has no effect upon the gross physical behavior and properties of the material; therefore, radioactive and nonradioactive aerosols behave in the same manner.

The collection of gas samples and their analysis for radioactive content must be related to the objectives of the program. These objectives usually will dictate the type of sample and the extensiveness of sampling and analysis. They may require sampling trains for both gas and particulate samples, stack, container, or open-air sampling methods, and either continuous or intermittent sampling.

TABLE 21-2-2
CLASSIFICATION OF AEROSOLS

Name	Type of Particle	Diameter Size Range (μm)	Remarks
dust	solid	> 1	Generated by mechanical processes.
fume	solid	< 1	Formed by the condensation of vapors of solid matter after volatization from the molten state.
smoke	solid	0.001 to 1	Incomplete combustion products of carbonaceous material.
mist	liquid	40-500	Formed by condensation of vaporized liquids.
fog	liquid	< 40	Formed by condensation of vaporized liquids.
spray	liquid	> 10	Mechanical dispersoid of liquid origin.

SAMPLING "TRAINS"

A gas sampling train is a system composed of components that have different functions. Such a system might include one or more sample collectors, a gas mover, a gas-flow measuring device, a contaminant detector, and temperature-measuring devices. Figure 21-2-2 is a block representation of this type of train system.

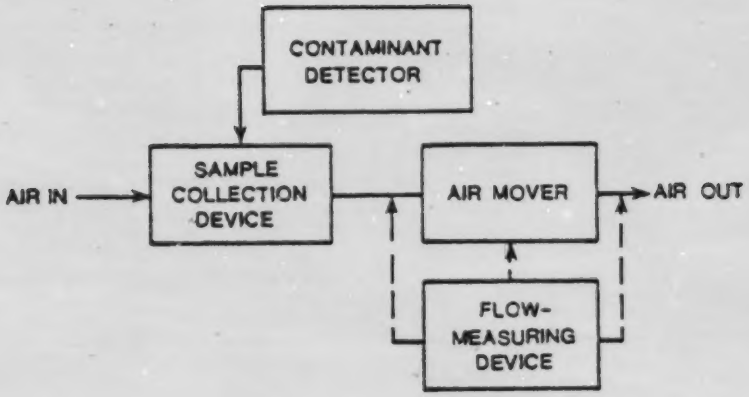


Figure 21-2-2. Sampling train.

The gas components of interest are collected in the sample-collection device. The sample may be collected in its original form or converted to some more convenient form for ease in handling and counting. Usually a separate collection device is used for each component of a gaseous waste, but not necessarily for each radionuclide.

The contaminant detector usually is some device for the measurement of radioactivity. Such detectors normally measure a particular type of activity, but may be used for mixed measurements. The detector is not always a part of the primary sampling train, but ultimately is used to determine the radiation present.

The flow-measuring device indicates the volume of gas sampled by either direct or indirect methods. Knowledge of the volume of gas sampled is necessary in order to give meaning to the resultant sample count rate.

The purpose of the air mover is to create a proper, uniform flow of gas through the sample-collecting device.

The temperature-measuring device is used in conjunction with the flow-measuring device to convert results to "standard volume."

The sampling train depicted in Figure 21-2-2 is not representative of all gas-sampling systems. Some have more, and some have fewer, components. Additional requirements may call for a sampling probe ahead of the sample-collection device or a moisture trap following the sample collector.

Some components of a sampling train may perform more than one function – an example being an evacuated flask that serves simultaneously as a sample collection device, as a gas mover, and as a volume-measuring device. In this case, a single component serves three functions.

Component sequence may vary in a sampling train. Frequently the sample-collection device is located ahead of the gas mover; this arrangement prevents contamination or removal of material from the sample by the gas mover.

Since each sampling situation is almost unique, each sampling train may be assembled of seemingly unrelated components. Although some sampling trains can be purchased "complete" from a manufacturer, the majority are assembled from components.

TECHNIQUES FOR GAS SAMPLING

Instantaneous, or "grab," samples normally are collected by using evacuated flasks or by water displacement. Integral, or continuous, sampling makes use of various techniques, including absorption, adsorption, and freezing.

"Adsorption" occurs when a material is attracted to the surface of a solid and is retained there. This is a very effective method for the capture of the so-called "non-reactive" noble gases, such as argon, krypton, and radon.

"Absorption" is the assimilation of molecules into a solid or liquid to form a solution or a compound. It is a common collection technique for carbon-14, iodine-131, and sulfur-35.

Condensation, or freezing, is a method of collection that involves drawing the gas through a trap at low temperature. It is very effective for the noble gases, carbon dioxide, and water vapor.

THE SAMPLING OF PARTICULATES

Four basic techniques account for the majority of particulate sampling techniques. These techniques are as follows:

- Sedimentation.
- Inertia.
- Electrostatic precipitation.
- Filtration.

Devices for sedimentation sampling depend upon the force of gravity to separate the particulates from the gases. The particulates usually are caught on a tray in a dry, tacky substance or in a liquid such as water. The sedimentation technique may be utilized to inform the health physicist as to the quantity and nature of radioactive contamination that is being deposited out of the atmosphere.

Inertial sampling devices include cyclones, impingers, and impactors. All of these devices depend for collection upon the inertial force of the particulates in a moving gas stream.

Electrostatic precipitators induce an electrostatic charge on the particulates and cause them to be attracted to a charged filter media.

Filtration probably is the most versatile of the sampling methods. Selection of filter media, pore size, and thickness provides a wide range of selectivity in the sample collection of particulate material.

These techniques may be used individually or in any combination to custom tailor sampling for a particular application.

INTERMITTENT AND CONTINUOUS SAMPLING

Gas sampling for radioactivity usually is categorized by the time required to collect the sample. Those samples collected in less than 30 minutes are classified as intermittent, or grab, samples. Samples that require 30 minutes or longer to collect are integrated or continuous samples. Both have their specific uses.

An intermittent, or grab, sampler includes a sample collector, a gas-measuring device, and a gas mover. Many grab-sampling devices perform all three functions. If the apparatus includes an automatic timer to turn the equipment on and off at various time intervals, it may be referred to as a "sequential sampler." Table 21-2-3 is a comparison of the advantages and disadvantages of intermittent, or grab, sampling.

TABLE 21-2-3

EVALUATION OF INTERMITTENT SAMPLING

Advantages	Disadvantages
1. Will indicate airborne concentrations at a precise time; may be valuable in identifying a specific source of contamination.	1. Could miss peak concentrations that occur between samples.
2. Several samples taken over a known period can indicate cyclic variations in the concentrations.	2. A large number of samples is required if an evaluation of a worker's daily exposure is to be made.
3. May have lower cost than continuous sampler.	3. Due to small sample volumes collected, will need high concentrations of radioactivity in order to detect anything.
	4. Measurement of the radioactivity content may require several man-hours if analysis has to be done separate from the sample collection.

Continuous samplers often include the same components as grab samplers, except that they may be physically larger and are equipped with detectors and a continuous readout device. Most of the continuous samplers are designed to be operated over extended periods of time. Table 21-2-4 gives a comparison of the advantages and disadvantages of continuous gas sampling.

TABLE 21-2-4

EVALUATION OF CONTINUOUS SAMPLING

Advantages	Disadvantages
1. Use of continuous air-measuring equipment usually decreases the number of man-hours required for sampling and analysis.	1. Can mask the peak concentrations.
2. May detect peak concentrations that would have been missed by intermittent sampling.	2. May not be able to relate to concentrations emitted by cyclic variations in a process.
3. May be able to show correlations between radioactivity levels and other continuously-recorded parameters such as visibility, etc.	3. Measurement of the radioactivity content may require several man-hours if analysis must be done separate from the sample collection.
4. Might be able to accomplish sampling and analysis by use of one piece of equipment.	4. Cost may be higher than for intermittent sampling devices.
5. Provides more complete information on changes in atmospheric pollution at a given point over a period of time. This information can be related to the general exposure of a person.	

As stated previously, both continuous and intermittent sampling have their uses. Selection of the procedure and technique must be in accordance with the specific objectives

of the sampling program. In some cases, where a very generalized type of survey is indicated, multiple combinations may be incorporated, utilizing both grab-sampling and continuous-sampling methods.

SAMPLER SELECTION FACTORS

Gas samplers, because of the variety of sampling problems, must be flexible; that is, adaptable to a variety of conditions. Because of this, any particular sampling technique cannot be superior to all other methods for every application. The final selection of a sampler, then, should be based upon several criteria. Criteria for condsideration in selection of a sampler include the nature of the radioactive gas, the objective of sampling, and the sample size required for analysis. Usually, several sampling methods will satisfy the criteria, and the final choice becomes a matter either of financial limitations or of the personal preference of the operator.

THE NATURE OF THE GAS

Probably the most important factors in the selection of a gas-sampling method are the physical and chemical characteristics of the gas. These factors include whether or not the gas contains particulates, and if so, the probable size of the particles, vapor pressure, solubility, density, dew point, and chemical reactivity. Each of these factors will require consideration during selection of particular materials and techniques for sampling.

SAMPLING OBJECTIVES

The specific objectives for sampling may determine both the type of sampling to be performed and the specific sampler to be used, although this may not always be true.

SAMPLE SIZE

Some procedures require a specific minimum quantity of material for accuracy. The sample size then should be large enough to ensure that these quantities are present. In general, the sample should be large enough to ensure that there will be several times the minimum measurable quantity of the material sought.

There are maximum limits to be considered, as well. Some determinations are adversely affected by samples too large in size. When a sample contains a very high concentration of a material, errors may be introduced when only small portions of material can be taken.

Still other factors that relate to sample size are the rate of sample collection and the efficiency of the sampling device. These may be mutually interactive or may be considered separately.

CALCULATION OF ACTIVITY

The radioactivity of gaseous radioactive waste is usually reported as an activity concentration. Items that apply to the calculation of activity concentration include

the sample volume, the quantity of the radionuclide present, and the decay corrections.

The "sample volume" may be the actual physical volume of the sample, or it may be a simple rate-time calculation. Equation 21-2-1 can be used to convert sample collection rate to sample volume.

$$V = R \times T \qquad \text{Equation 21-2-1 (Equation = Eq.)}$$

where:

V = volume of the sample, in liters.

R = rate of sampling, usually in liters per minute.

T = time of sampling, usually in minutes.

An example of the use of this equation follows.

EXAMPLE	
Given:	A sample of a radioactive gas is collected at the rate of 17 liters per minute for 90 minutes.
Find:	Volume of the sample.
Solution:	From Equation 21-2-1 –
	$V = R \times T$
	$= 17$ liters/minute $\times$ 90 minutes
	$V = 1530$ liters
NOTE: The minutes cancel out.	

Equation 21-2-2 is the general equation for expressing the quantity of a radionuclide in a sample.

$$q_i = \frac{(CR)_i}{(CE)_i \ 2.22 \times 10^{12}} \qquad \text{Eq. 21-2-2}$$

where:

q_i = quantity of the radionuclide i on the collecting medium.

$(CR)_i$ = net count rate (cpm) due to radionuclide i in the sample in a given counter.

$(CE)_i$ = counting efficiency of the given counter for the radionuclide i (cpm/dpm).

2.22×10^{12} = conversion factor to convert dpm to curies.

An example of the use of this relationship follows.

EXAMPLE	
Given:	A sample of radioactive gas produces 5.7×10^6 counts per minute on an instrument that has an efficiency of 0.37 for the nuclide counted.
Find:	Number of curies in the sample.
Solution:	From Equation 21-2-2 –

$$q_i = \frac{(CR)_i}{(CE)_i \ 2.2 \times 10^{12}} \qquad \begin{matrix}(CR)_i = 5.7 \times 10^6 \\ (CE)_i = 0.37\end{matrix}$$

$$= \frac{5.7 \times 10^6 \text{ cpm}}{0.37 \text{ cpm/dpm} \times 2.22 \times 10^{12} \text{ dpm/Ci}}$$

$$q_i = 6.94 \times 10^{-6} \text{ Ci or } 6.94 \ \mu\text{Ci}$$

Occasionally, short-lived radionuclides are measured some time after the sample has been taken. Such later determination of the activity at the time of sampling is accomplished by correcting for the radionuclide decay between the end of the sampling and the midpoint of the counting time. The corrected activity is calculated from Equation 21-2-3.

$$q_i \text{ corrected} = \frac{q_i}{e^{-\lambda_i t_d}} \qquad \text{Eq. 21-2-3}$$

where:

q_i corrected = quantity of i radionuclide at the end of sampling.

λ_i = decay constant for i radionuclide ($time^{-1}$).

t_d = time period between the end of sampling and the midpoint of counting.

q_i = quantity of radionuclide i on the collecting medium.

EXAMPLE	
Given:	A sample of ^{131}I contained 6.94 curies 47 hours after sampling. $\lambda_i = 3.58 \times 10^{-3}$/hr.
Find:	Radioactive content at the end of sampling.
Solution:	$q_i \text{ corrected} = \frac{q_i}{e^{-\lambda_i t_d}}$ Eq. 21-2-3

$$= \frac{6.94 \text{ Ci}}{e^{-(0.00358 \times 47)}}$$

$$= \frac{6.94 \text{ Ci}}{0.845}$$

$$q_i \text{ corrected} = 8.21 \text{ Ci}$$

There are times when more specific corrections must be used in calculations, but these general equations will suffice for many purposes.

THE SAMPLING OF RADIOACTIVE LIQUIDS

The principles of representative liquid sampling are well established and apply to sampling for radioactivity examinations.

Because some radioactive elements may be present only in submicrogram quantities, a significant fraction of the material may be lost by adsorption to the surface of the containers used in collection and processing. Likewise, the radionuclides may be wholly or partially adsorbed on the surface of suspended particles.

SAMPLE CONTAINERS

When radioactive liquids are sampled, special consideration must be given to the problem of deposition of radioactive nuclides on the walls and surfaces of containers and transfer equipment. This problem is twofold in that this

may cause the loss of radioactivity from the sample; cause the consequent inaccuracy in the ultimate results of the sampling program; and cause the possible contamination of future samples due to reuse or improperly-cleaned labware.

REPRESENTATIVE SAMPLES

Careful planning by the collector analyst concerning the technique for collection of the sample and the method used for analysis of the sample will result in the prevention of inappropriate sample-collection methods and inaccurate data. The sample must be truly representative of the existing conditions, and must be handled in a manner that prevents its deterioration or contamination before it reaches the laboratory.

Prior to collection of the sample, the container should be rinsed several times with the liquid to be collected. Representative samples of some liquids can be obtained only by making composites of samples that have been collected over a period of time or at many different sampling points. Local conditions cause so much variation in collection details that no specific procedures are universally applicable. Often, analysis of several different samples is more informative than analysis of one composite.

A record should be made of every sample collected; and every container should be identified, preferably by an attached and appropriately-inscribed tag. The tag should contain sufficient information to allow the sample to be positively identified at a later date and should include the collector's name, the date, the time, and the exact location of the sample collection. Temperature and other

data, such as wind velocity and direction, may or may not be required, depending upon the type of sample being collected. Although it is not possible to make specific statements regarding collection procedures, some general "rule-of-thumb" remarks may be stated as follows:

- Before samples are collected from a pipe system, the system should be flushed sufficiently to ensure that the sample will be representative of the supply and not of the stagnant ends. This procedure requires knowledge of the length and diameter of the pipes and the velocity flow.
- Samples taken from a river or stream may vary with depth, flow, and distance from the shore. If possible, an integrated sample should be taken from top to bottom in mid-stream in order to make the sample composite according to flow; however, if only a grab sample can be collected, it is best taken at mid-depth in the middle of the stream.
- When the purpose of testing is to determine average conditions, a 24-hour composite sample is considered standard. If, however, the purpose is to determine peak concentrations or the concentration at a specific time, then grab samples are necessary. The sampling interval may be as short as five minutes or as long as several hours.
- Some samples may contain organic matter that has been attacked by bacteria. A preservative can be added to these samples to prevent bacterial growth, or the samples can be refrigerated. Either method usually is acceptable, although the choice of method probably should be made by the analyst rather than by the collector.

SAMPLE SIZE

The sample should be of such a volume that a reasonable counting portion of the radioisotope in question can be obtained if it is present. This may require several liters for low-level liquids or less than a liter for high-level liquids. Normally, a 2-liter sample should be sufficient for most determinations. When a grab sample is taken, the sampling container should hold at least half again as much as the container into which the sample is to be placed; for example a 2-liter sample requires a 3-liter sampler.

A composite sample should be sized to its ultimate analysis, just as with a grab sample. In fact, a composite sample is a series of grab samples mixed together to represent the average composition. A weighted composite sample is one whose fractional parts are sized according to the flow rate of the liquid being sampled. Size of the individual portions of the sample can be calculated from Equation 21-2-4.

$$V_s = \frac{V_t}{N} \times \frac{FR_i}{FR_{avg}} \qquad \text{Eq. 21-2-4}$$

where:

V_s = volume of the sample at the sampling time.
V_t = volume required for the final composite.
N = total time of sampling divided by the sampling interval, plus 1.
FR_i = flow rate at the time of sampling.
FR_{avg} = average flow rate.

EXAMPLE

Given: A liquid waste discharge is to be sampled at two-hour intervals during eight hours to produce a 2-liter, weighted composite sample. The average flow rate is 31.54 l/sec.

Find: The size sample required when the flow rate is 44.16 l/sec.

Solution: From Equation 21-2-4 –

$$V_s = \frac{V_t}{N} \times \frac{FR_i}{FR_{avg}}$$

V_t = 2 liters = 2000 ml $\qquad$ FR_i = 44.16

$N = 8/2 + 1$ $\qquad$ FR_{avg} = 31.54

$$V_s = \frac{2000 \text{ ml}}{(8/2) + 1} \times \frac{44.16 \text{ l/sec}}{31.54 \text{ l/sec}}$$

V_s = 560 ml.

THE SAMPLING OF SOLID MATERIALS

The sampling of a large bulk of waste solid material presents difficulties that vary from case to case. With ores, tailings, and similar material, the amount of gross material that must be taken depends upon particle size. As a general rule, the larger the pieces, the larger the gross sample. Often, the "fines," or dust, differ in composition from the larger pieces, and segregation may occur because of differences in density. When this happens, the fine and coarse material must be sampled separately and the samples combined to give coarse and fine material in the original proportions, as determined by screening experiments.

REDUCTION OF THE GROSS SAMPLE

There are several methods of reducing the size of the gross sample. This is necessary to produce a representative sample that might be reasonably handled in the laboratory.

One method used for waste that exhibits low-level activity is the rejection of alternate shovels. The material is reduced in size to approximately 1" chunks and formed into a conical pile. The conical pile then is extended to form a long pile, and a sample is prepared by the taking of and the rejecting of alternate shovels full of the material. If the sample is too large, the material may be reduced further in size and the procedure repeated.

Quartering is another method used for size reduction of samples. This method requires that the waste be crushed and made into a well-mixed conical pile. Opposite quarters of the pile are rejected, and the process is repeated with the remainder until the sample is of manageable size.

A third method of sample reduction is called "riffing," which involves the use of a mechanical "riffer" device that rejects half a sample at a time. The riffer consists of an arrangement of chutes or baffles such that, when the original sample is passed through the device, it is reduced, in one operation, to one-half its original size.

THE SAMPLING OF METALS

Technicians sample metals in the form of "pigs," "billets," or large pieces by sawing or drilling at a number of points to obtain representative samples. Such sampling usually is preceded by spot analysis of the sample points.

SAMPLE PREPARATION AFTER COLLECTION

After a radioactive waste sample is collected, it must be prepared for counting. The procedures involved may be as simple for the technician as removing the sample from the collection device and placing it in the counter, or the procedures may involve complex chemical separation and preparation.

The principal physical process is the use of heat either to dry or to ash the sample. Occasionally, a sample may require freezing.

Chemical processes involved in sample preparation may be simple precipitations or may involve complex solvent-extraction methods. The many varied methods of sample preparation are covered more thoroughly in Course 20, "Radiation Monitoring Techniques," and in Course 22, "Advanced Radionuclide Analysis."

RADIOASSAY

The ultimate goal of sampling is the determination of the radioactive content of the material. This determination is accomplished through a combination of sample-preparation and counting techniques. In the case of a sample that contains an unknown quantity of an unknown isotope the analyst may begin by simply counting to determine the types of radiations present. This procedure may advance to alpha, beta, or gamma spectroscopy for identification of the isotope present. Spectroscopy will be followed either by comparative, or by absolute, counting to determine the actual amount of radioactive isotope present. If, on the other

hand, the identity of the isotope is known, the assay may proceed directly to the comparative, or to the absolute, counting.

THE REPORTING OF RESULTS

The results of a radioassay of a waste material frequently are expressed in the quantity of the isotope per unit volume or mass. Liquids and gases usually are reported in unit activity per unit volume, and solids normally are reported as unit activity per unit mass.

ESTIMATION OF ACTIVITY

In the case of high-level solid wastes, representative samples of the radioactive material often can be obtained. When this happens, the protection team must rely upon poor samples, radiation field-measurement techniques, or a combination of these. Such measurements may be used with reasonable accuracy, but all persons who use the data thus obtained must be aware of the limitations of these techniques.

EXERCISES

1. Calculate the quantity of radioactive material present in a sample that produces 11,500 counts per minute in a counter that has an efficiency of 0.21 cpm/dpm for the particular isotope.

2. Calculate the quantity of liquid to be taken from a wastewater stream to produce a composite sample of 2 liters if the stream is to be sampled every hour for 8 hours. The average flow of the stream is 89 liters per second. The flow rates at the time of sampling are as follows:

T_0 = 77 l/sec.
T_1 = 80 l/sec.
T_2 = 88 l/sec.
T_3 = 91 l/sec.
T_4 = 95 l/sec.
T_5 = 93 l/sec.
T_6 = 85 l/sec.
T_7 = 103 l/sec.
T_8 = 89 l/sec.

MATERIALS

High-volume air sampler.
Glass fiber filter mats for sampler.
"Pancake" GM counter.
2-inch diameter planchets.
Drying oven.
50-ml centrifuge.
50-ml contrifuge tubes.
Compressed nitrogen.
Nitric acid concentrate.
Hydrochloric acid – one concentrated type and one 0.5 N type.
Hydrogen sulfide.

Ammonium hydroxide.
Ammonium phosphate.
Silver nitrate molar 0.1 M.
Solution that is 0.1 molar in Cl, Br, I, Cu, As, Fe, Y, Co, Mn, Zn, Ba, Sr, Ca, Na, and K as carriers.
Multichannel gamma scintillation spectrometer.
100-ml simulated waste sample, containing 0.5 μCi of each of the following radioisotopes: ^{131}I, ^{82}Br, Cu, ^{90}Sr, ^{60}Co, ^{65}Zn, ^{137}Cs, ^{22}Na.

PROCEDURES

DETERMINATION OF GROSS BETA RADIOACTIVITY IN AIR

Explanation: The general method of sampling a radioactive gas and air is the same; therefore, practice in air sampling then should prepare the student for other types of sampling.

1. Mount the glass-fiber filter on the high-volume sampler.
2. Sample for 24 hours, taking care to stop the sampler 4 hours before the sample is to be counted.
3. Cut a 2-inch diameter circle from the glass-fiber filter; place this filter portion in a planchet; and dry it in a drying oven for 1 hour at 98°C.
4. Remove from the oven and count on the "pancake" beta counter for 10 minutes.
5. Record data in Data Table 21-2-1.
6. Calculate total beta activity of sample.

7. Calculate concentration of beta activity in the air.

IDENTIFICATION OF RADIOISOTOPES IN LIQUID WASTE

Explanation: The most common approach to the identification of radionuclides in a liquid waste is through the application of gamma scintillation spectroscopy. Accurate interpretation of the spectral data requires that a particular sample should not contain more than four or five different radionuclides. For this reason, samples usually are separated chemically into chemical groups before they are counted.

1. Place 25 ml of the radioactive, simulated waste sample in a 50-ml beaker.
2. Bubble nitrogen through the liquid for 5 minutes to remove radioactive gases.
3. Acidify by adding 0.5 ml nitric acid.
4. Add 5 ml of carrier solution.
5. Add 15 ml of 0.1 M silver nitrate, and stir.
6. Filter through a glass-fiber filter, saving the filtrate.
7. Wash the precipitate with water; mount; and count on a gamma scintillation spectrometer. Designate as the silver group. (AgCl, AgBr, AgI)
8. Add 2 ml of 0.5 N hydrochloric acid to the filtrate, and saturate with hydrogen sulfide.
9. Filter through a glass-fiber filter, saving the filtrate. Wash the precipitate with water; mount; and count on the gamma spectrometer. Designate as the acid sulfide group. (Cu^5 + As_2 S_3)

10. Transfer the filtrate to a 150-ml beaker; add 1 ml of concentrated hydrochloric acid; and boil until clear.
11. Add 5 ml of concentrated nitric acid, and boil for 5 minutes.
12. Cool, and add a volume of concentrated hydrochloric acid equal to the volume of the solution.
13. Neutralize with concentrated ammonium hydroxide; and filter, saving the filtrate.
14. Wash, mount, and count the precipitate. Designate as the "hydroxide group" (Fe + Y hydroxides).
15. Saturate the filtrate with H_2S.
16. Filter through a glass-fiber filter, saving the filtrate.
17. Wash, mount, and count the precipitate on the gamma spectrometer. Designate as the basic sulfide group (CO^5, Mn^5, Zn^5).
18. Acidify the filtrate with hydrochloric acid, and boil for 5 minutes.
19. Add 2 grams of diammonium hydrogen phosphate.
20. Add concentrated ammonium hydroxide until the solution is strongly basic.
21. Filter through a glass-fiber filter, saving the filtrate.
22. Wash the precipitate with water made slightly basic with a few drops of ammonium hydroxide. Mount, and count on the gamma spectrometer. Designate as the "alkaline earth group" (Ca, Ba, Sr phosphates).
23. Transfer an aliquot of the filtrate to a scintillation-counting vial, and count on the gamma spectrometer. Designate as the "soluble group" (N_2 and other soluble ions).

24. Identify the gamma spectra of all samples by comparison with the spectra of known samples.
25. Record findings in Data Table 21-2-2.

DATA TABLE 21-2-1

A. Volume of Air Sampled

	Date	Time	Flow
Start			1/min
Finish			1/min
Total			1

B. Activity

Date	Time	Total Count	Count Time	Gross cpm	B.G. cpm	Net cpm

DATA TABLE 21-2-2

	Isotope
Silicon	
Acid Sulfide	
Hydroxide	
Basic Sulfide	
Alkaline Earth	
Soluble	

REFERENCE MATERIALS

Ayres, J. A., ed. Decontamination of Nuclear Reactors and Equipment. New York: The Ronald Press Co., 1970.

Gilmore, William R., ed. Radioactive Waste Disposal: Low- and High-Level. Park Ridge, NJ: Noyes Data Corp., 1977.

Neal, A. W. Industrial Waste, Its Handling, Disposal, and Reuse. London: Business Books Limited, 1971.

1. List the inherent chemical and radiological dangers of a sample of waste diethyl ether than contains 5 μCi ^{239}Pu per liter of solution.

2. Write the procedure for collecting an eight-hour composite sample at a plant wastewater discharge site.

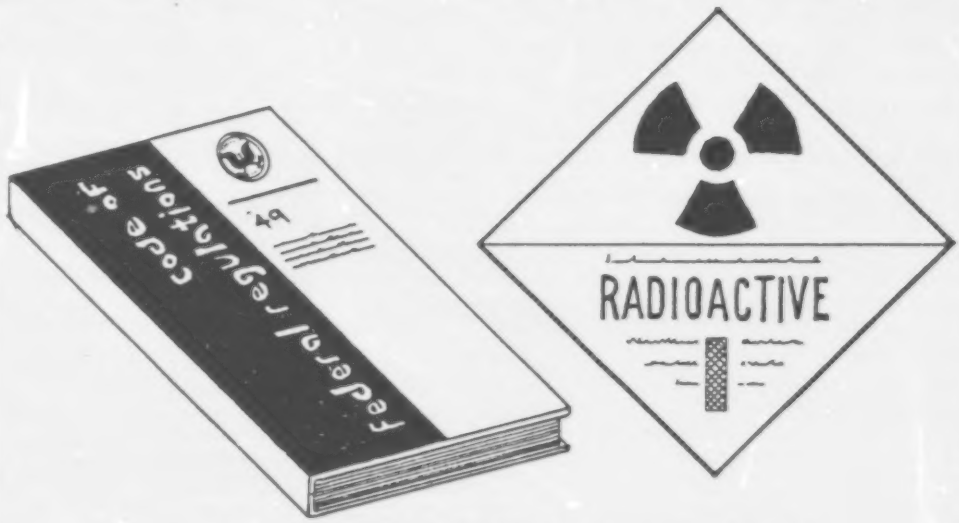
3. List the special considerations necessary when sampling the gaseous discharge from a nuclear facility.

4. A grab sample of liquid was found to contain ^{131}I sufficient to produce 17,500 counts per minute on a counter that has an efficiency of 0.42 for counting ^{131}I. The midpoint of the counting time occurred 22 hours after the sample was taken. The volume of the liquid used to prepare the counting sample was 25 ml. What was the ^{131}I content, in microcuries per milliliter, of the original solution at the time of sampling?

NUCLEAR TECHNOLOGY

MODULE 21-3

RADIOACTIVE WASTE DISPOSAL REGULATIONS



RADIOACTIVE MATERIALS DISPOSAL
AND MANAGEMENT

COURSE 21

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

COURSE 21 RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

MODULE 21-1 Radioactive Waste Disposal Procedures

MODULE 21-2 Routine Sampling of Radioactive Waste

MODULE 21-3 Radioactive Waste Disposal Regulations

MODULE 21-4 Measurement of External Radioactive Contamination

MODULE 21-5 Regulations for Transportation of Radioactive Materials

MODULE 21-6 Packaging and Monitoring of Radioactive Materials for Shipment

MODULE 21-7 Leak Tests of Sealed Radioactive Sources

Copyright© 1980

Center for Occupational Research and Development, Incorporated
4800 Lakewood Drive, Waco, Texas 76710

Reproduction or publication of the content in any manner, without the express permission of the Center for Occupational Research and Development, Incorporated, is prohibited. No liability is assumed with respect to the use of the information herein.

INTRODUCTION

The regulation of radioactive waste disposal falls within the jurisdiction of several federal and state bodies and under international agreement. These regulations specify isotopes, amounts, packaging, transportation, and methods of disposal. This module provides an overview of some of these regulations, especially those regulations that are likely to confront the technician on the job.

MODULE PREREQUISITES

The student should have completed Course 1, "Radiation Physics"; Course 2, "Radiation Protection I"; Course 11, "Radiation Detection and Measurement"; Course 17, "Radiation Protection II"; Course 19, "Radiation Shielding"; and modules 21-1, "Waste Disposal Procedures," and 21-2, "Routine Sampling of Radioactive Waste."

OBJECTIVES

Upon completion of this module, the student should be able to:

1. List the goals of the NRC and DOE in the regulation of radioactive waste disposal.
2. Outline the NRC regulations that relate to waste disposal.

3. Determine which agency or agencies have jurisdiction over a specific problem in radioactive waste disposal.
4. List two international agreements that regulate radioactive waste disposal.
5. List the agencies responsible for the monitoring and enforcement of regulations concerned with radioactive waste disposal.
6. Given a specific description of a sample of nuclear waste material, determine if it is a high-level, or a transuranic, material.

AGENCY GOALS IN REGULATION

The basic policy statements concerning the goals for radioactive waste management vary somewhat, depending upon the governmental agency involved. This variance is understandable since the missions of each agency are different; however, all are concerned with the protection of the public health and of the environment.

THE NUCLEAR REGULATORY COMMISSION (NRC)

The goals and responsibilities of the NRC are derived from the Atomic Energy Act of 1954, as amended. These goals are as follows:

1. The isolation of radioactive wastes from man and his environment for sufficient time to ensure public health and safety and the preservation of environmental values.
2. Reduction of the following items to as low a level as is reasonably achievable:
   - Risk to the public health, both from the chronic exposure associated with waste management operations and from the possible accidental releases of radioactive materials from waste storage, processing, handling, or disposal.
   - Long-term social commitments such as land-use withdrawal, resource commitment, requirement for surveillance, site proliferation, etc.

Certain social, economic, and environmental goals have also been expressed by the NRC. The report of a recent NRC task force on radioactive waste goals and objectives reflects a concern with the institutional arrangements necessary for radioactive waste managment, economic impacts, foreclosure of future options, time frames for action, distribution of hazards and benefits, uncertainties of decision making, and the involvement of the public in radioactive waste management decisions.

The NRC implements its responsibilities by promulgation of rules and regulations published in the Code of Federal Regulations (CFR), Title 10.

In general, NRC regulations for radioactive waste disposal cover releases to the atmosphere, streams, and ground. These regulations are as follows:

- 10 CFR, Part 20 – "Standards for Protection against Radiation."
- 10 CFR, Part 60 – "Disposal of High-level Radioactive Wastes in Geologic Repositories; Proposed Licensing Procedures."
- 10 CFR, Part 72 – "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation."

THE DEPARTMENT OF ENERGY (DOE)

The United States Department of Energy's goals are somewhat similar. DOE's goals are to provide the effective management of nuclear wastes in a manner that effectively protects man and his environment. In particular, DOE's goal

concerning high-level commercial radioactive waste is to provide multiple terminal storage sites on time to receive solidified waste without inhibiting the power industry.

THE ENVIRONMENTAL PROTECTION AGENCY (EPA)

The statements of the Environmental Protection Agency have primarily focused on technological safety. The position of the EPA remains as follows: "Waste management means containment of radioactive materials until they have decayed into innocuous levels. The objectives that EPA has are to minimize exposure to present and future populations and to avoid dilution into the biosphere."

THE DEPARTMENT OF TRANSPORTATION (DOT)

The goal of the Department of Transportation is to maintain safety and surveillance while radioactive waste material is being transported by all modes and all means. The DOT regulations usually are based on NRC regulations. To avoid the duplication of regulatory efforts, the NRC and the DOT adopted a program whereby each would operate in the areas of its special competence, thus minimizing the duplication of effort.

OTHER REGULATORY BODIES

These four agencies just discussed by no means constitute all the regulatory groups concerned with radioactive waste materials. Similar agencies and others within each state hold jurisdiction through various agreements and requirements. There are also international agreements concerning radioactive waste materials. The major emphasis by any of these, as in the four previously mentioned, is upon public health and safety.

ORGANIZATION

Policies can be effective only if they are applied by some institutional organization. Such organizations must function on three levels: (1) waste management, (2) regulation of waste management, and (3) research and development of improved waste management methods.

MANAGEMENT

The term "waste management," as used by the nuclear industry, refers to the actual performance of the activities, both physical and administrative, required for long- and short-term handling of radioactive materials. Long-term activities include only retrievable storage and permanent disposition. Anything else must be termed short-term, regardless of when the activity occurs. Some of these short-term activities are temporary storage, treatment, packaging, and

transportation. The responsibility for managing these activities is divided between private industry and the DOE.

The division of radioactive waste management responsibility between the DOE and private industry occurred through the Atomic Energy Act of 1954, its amendments, and the Energy Reorganization Act of 1974. These acts divide the responsibilities between DOE and the licensees of NRC or Agreement States. DOE's radioactive waste management facilities are not actually operated by DOE personnel. Independent contractors actually perform almost all the activities, subject to DOE management policies.

NRC licensing places the responsibility for management of commercial high-level (HL) wastes with the licensee up until the time it is delivered to a DOE facility for final disposition. Current regulations require that the licensees solidify liquid high-level waste within five years of its generation and that the solidified waste must be delivered to a DOE repository within five years after it has been solidified. Private industry, then, is responsible for the short-term management of radioactive waste, while the responsibility for long-term management is reserved to the federal government.

High-level radioactive waste management responsibility for waste produced by the manufacture of nuclear weapons and nuclear propulsion systems is vested entirely in the federal government. The agencies involved are the Department of Defense (DOD) and DOE. The DOD managerial responsibility for military radioactive waste is relatively minor since it handles naval reactor spent fuel elements for only a short time before transfer to DOE. The DOD is not responsible for the high-level waste from nuclear weapons production; this respon-

sibility falls to DOE since DOE produces the plutonium for nuclear weapons and actually manufactures the warheads.

Current laws and NRC regulations allow private industry, licensed by the NRC, to have long- and short-term responsibility for commercial transuranic (TRU) waste material. There have been, however, proposals by the NRC to alter this procedure with respect to the long-term responsibility. These regulations would prohibit the burial of any TRU waste and would require the licensees to ship all transuranic waste to DOE within five years of its generation. Presently, transuranic waste material is not being buried.

Management of military transuranic waste material is the short-term responsibility of the Department of Defense (DOD) and the long-term responsibility of DOE. The Department of Defense manages relatively small amounts of transuranic waste material from the naval propulsion program and nuclear weapons component assembly and maintenance. The DOD usually transfers these waste materials to DOE as soon as possible. Some buried military transuranic waste was inherited by commercial burial-site operators when they took over sites that previously had been operated by the AEC. Additionally, the commercial site at Hanford, Washington, continues to receive transuranic waste material of the nuclear Navy.

REGULATION

Regulations for the control of radioactive waste products are in the developmental stages. Various efforts currently are being expended toward this development. Several technologies currently exist for the treatment and disposal

of radioactive waste material, but the decision on which to use and the resulting regulations is political. The NRC is actively pursuing a program for the development of regulations for radioactive waste. This involves the establishment of a research program to support the regulatory and licensing activities in the management of radioactive waste, the classification of types of nuclear waste material, the specification of the solid-form types that will be acceptable for high-level wastes, review of the requirements for commercial burial of low-level waste material, and coordination of the activities of federal agencies with those of the various state and local governments.

The authority to produce regulations that relate to radiation safety and to radioactive materials rests with the federal government. The Atomic Energy Act of 1954 and the Energy Reorganization Act of 1974 place the authority to establish criteria and standards for protection against radiation with the NRC. Figure 21-3-1 is the title page from the United States Nuclear Regulatory Commission Rules and Regulations.

The DOE is charged with development of the criteria and standards for its own operations. The EPA is also given some authority in the area of regulation. When the Federal Radiation Council was abolished, its authority to advise the President concerning radiation and to guide all federal agencies in the formation of radiation standards and the establishment and execution of programs of cooperation with states was given to the EPA. Under the 1970 reorganization plan, the responsibility for establishing generally applicable environmental standards for the protection of the general environment from radioactive material was transferred from

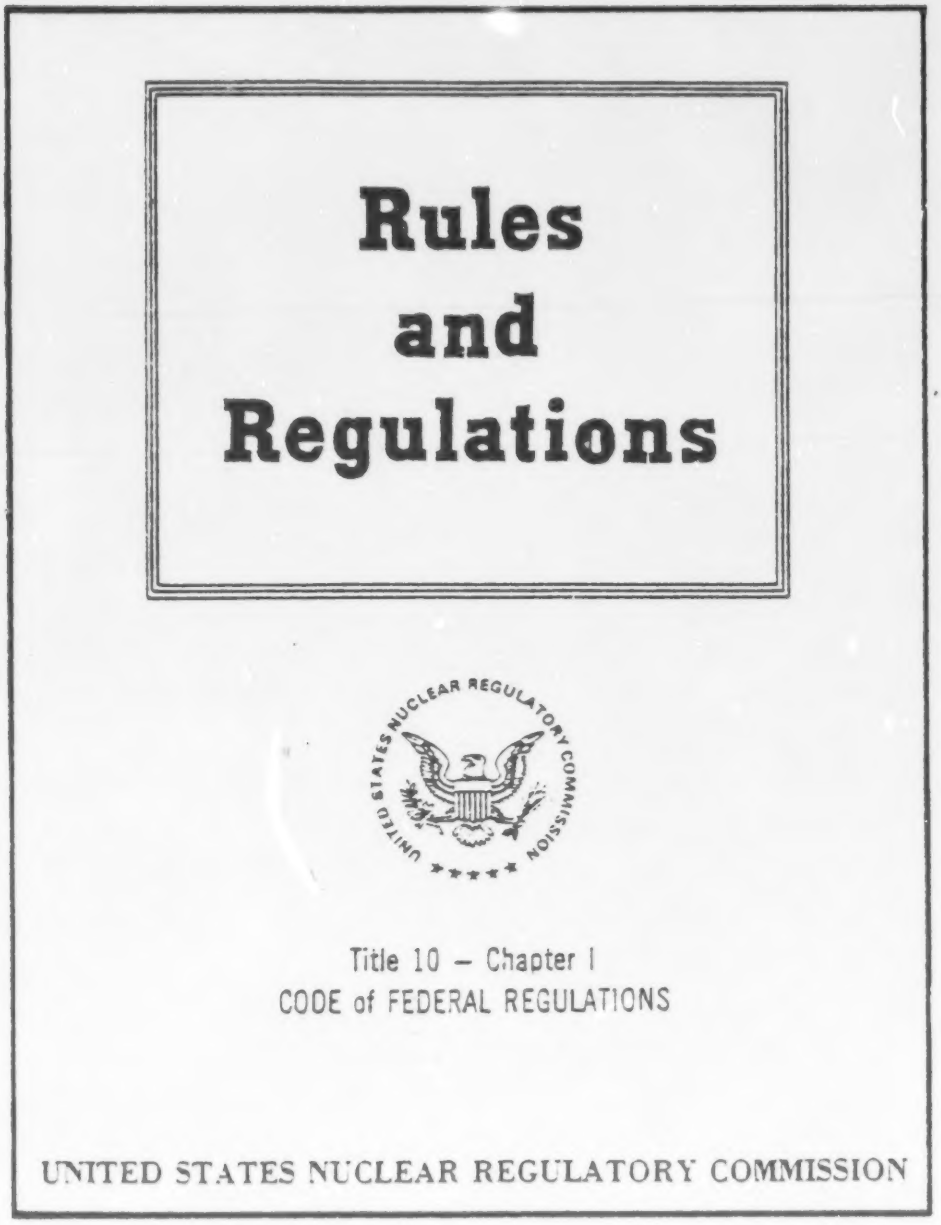


Figure 21-3-1. Title page from U.S. NRC rules and regulations.

the AEC to the EPA. The term "standards" was defined as limits on radiation exposures or levels, or concentrations or quantities of radioactive material in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material. Thus far, the EPA has interpreted this to exclude the activities of NRC and DOE licensees that take place within the geographic confines of the licensee's facility; however, any and all activities that occur outside of these geographic confines fall within the jurisdiction of the EPA. Because of this, the EPA has the authority to set exposure standards for transportation of radioactive waste. Additionally, the EPA has attempted, on occasion, to expand its authority to include activities within the boundaries of NRC licensees or DOE facilities.

Presently, the most complicated portion of post-fission waste-product regulation is the granting of licenses and approval of activities. The general responsibilities for these functions rest with the DOE and the NRC, within their respective jurisdictions, although several other agencies have additional licensing authority.

DEPARTMENT OF TRANSPORTATION

The Department of Transportation (DOT) and the nuclear agencies hold joint responsibilities for the safe transportation of radioactive materials. This joint responsibility is the result of a series of legislations. In 1973, the DOT and the AEC joined in a Memorandum of Understanding to allocate duties in their areas of common jurisdiction. Their Memorandum recognized the DOT's authority to develop safety standards

for the packaging by shippers and the handling by carriers. This same Memorandum authorized the AEC to develop criteria for Type B packages of large-quantity radioactive materials and of fissile materials. Further, the agencies promised to enforce each other's standards and to exchange information before developing new regulations concerning the transportation of radioactive materials. Now that the AEC functions are divided between the DOE and the NRC, the Memorandum applies to both agencies. The NRC and DOE acknowledged this by adopting the appropriate AEC manual chapters into their regulations. It is also significant to note that the requirements of both agencies that shippers follow registration and approval procedures, closely parallels the DOT's regulations applicable to the shipment of nonradioactive hazardous materials.

The single exception to federal domination of radioactive waste transportation regulations occurs when less than critical mass quantities of special nuclear materials are transported within an agreement state. When this occurs, neither the DOT nor the NRC has jurisdiction. In this one special case, the state laws and regulations apply. This is a moot point, since all the agreement states require packaging to meet DOT regulations.

The federal transportation and packaging regulations for radioactive waste materials that have been in effect since 1968 are almost identical to the 1961 regulations of the International Atomic Energy Agency (IAEA). The IAEA, however, revised its regulations in 1973; and presently, both the DOE and the NRC are considering revision of their regulations to correspond to those of the international organization.

The recent increase in the number of incidents that involve the transportation of radioactive waste material has aroused public interest in the disposition of nuclear wastes. As a result, the NRC and the states have committed themselves to planning for emergency response, risk analysis, and environmental impact assessment. Such planning will not prevent incidents, but it will reduce greatly the problems that are produced by such.

> On October 29, 1979, the NRC amended its regulation for packaging and transportation of radioactive material. The amendments were published in the Federal Register on November 2, 1979 (44 FR 63083), and became effective on December 3, 1979. The amendments require all shipments of radioactive material made by NRC licensees, other than shipments subject to the regulations of the U.S. Postal Service, to be made in accordance with the regulations of the U.S. Department of Transportation. The regulations were amended to allow the NRC to inspect the activities of its licensees involved with shipment of radioactive materials.
>
> The NRC has issued guidelines which state how the NRC will enforce the new regulations. On December 3, 1979, the NRC issued a letter to inform all its licensees subject to this regulation of the new enforcement procedures.

THE ROLE OF THE STATES

Radioactive waste management regulation by the states is increasingly important. Several states, in fact, have challenged federal exclusive jurisdiction of radioactive waste regulation.

The U.S. Constitution established a federal government of limited powers and specifies that all authority not speci-

fically delegated to the federal government is reserved to the states. The consitutional power of the states is quite broad, and it allows them to regulate activities within their borders to ensure the public safety and health. Land use is primarily under state control. These two items place the regulation of radioactive waste materials well within the jurisdiction of the state; however, there are qualifications to this jurisdiction. One of these qualifications is the Supremacy Clause, which says that a state regulation must not conflict with valid federal laws or regulations. A second qualification is the Commerce Clause, which requires that state regulations must not produce an undue burden on interstate commerce. The first of these qualifications was affirmed by the U.S. Supreme Court in supporting the decision of the U.S. Court of Appeals concerning Northern States Power vs. Minnesota. The decision held that federal regulations on nuclear power plants preempt state regulations and that state regulations cannot be stricter than federal regulations.

A possible method of control that has not been tested thus far lies in the state land-use controls, which might be used effectively to zone out radioactive waste disposal sites. The disapproval of a site of operation, however, would require other reasons than the potential radiation hazard. Additionally, state or local government could not prevent the siting of a facility on federally owned land.

Political and economic influences on the laws that affect the federal-state relations are very real. Public opinion can and does influence regulation, and the people of a state can effectively stop activities allowed by the federal government.

Probably the greatest influence of a state in the regulation/decision-process occurs at the site approval stage of the federal licensing process. A state may exert great influence on siting and regulations that affect nonradiological safety if the influences are not applied to prevent location of the facility outright. Political pressures are very likely to continue to play very forceful roles in state and federal relations.

INTERNATIONAL REGULATION

Activities concerning radioactive waste materials may extend beyond the territorial jurisdiction of any country, and the effects of these activities may be felt in other countries. There is a need for some type of examination of these activities. If such activities are conducted by U.S. citizens, they are subject to regulation by the U.S., by the affected nation, by various international regulations, or by all three concurrently. The international problems of radioactive waste disposal are important, especially the dumping of materials into the ocean and the consideration of seabed and ice-sheet disposal of high-level radioactive waste.

The Marine Protection, Research and Sanctuaries Act gives the EPA the authority to issue permits for the transport of materials to be dumped in the territorial waters of the United States. The single exception is dredged materials, which fall within the jurisdiction of the Secretary of the Army. The dumping of high-level waste materials is specifically prohibited, but there is no prohibition about the dumping of transuranic waste. Since 1970, however, the United

States government has maintained a moratorium on the dumping of transuranic wastes. Thus far, neither the EPA nor the DOE has interpreted "dumping" to include burial of radioactive waste in the deep seabed under the ocean floor. The EPA has declared that such actions by U.S. citizens fall within its jurisdiction; however, this declaration, as well as the definition of dumping, probably will require legal clarification.

The United States has entered into a number of international multilateral agreements that affect the U.S. radioactive waste policy. Of these agreements, two are outstanding and hold major significance. The first is the United Nations Law of the Sea Convention on the High Seas. This agreement of 1958 applies to all areas of the sea not included in the territorial waters of some nation. It provides the foundations for attempts at protection of the maritime environment. Generally, the agreement nations are to exercise "reasonable regard to the interest of other states in their exercise of the freedom of the high seas." More specifically, the agreement nations are to produce their own regulations to prevent pollution form the exploration and exploitation of the seabed and its subsoil. Likewise, the agreement nations are required to take measures to prevent pollution of the seas from the dumping of radioactive wastes. Those who have agreed to this convention have a duty to cooperate with the International Atomic Energy Agency in taking measures to prevent the pollution of the seas or the air space above. These are not tight regulations, and the wording leaves much to interpretation, although cooperation with IAEA at least implies discussion before burial of high-level waste in the deep seabed. (Ocean dumping of low-level and transuranic waste is not affected by this convention, although the U.S. does not dump transuranic waste into the sea.)

The second notable agreement, the London Convention on Prevention of Marine Pollution by Dumping of Wastes and Other Matter, became effective in 1975. This agreement prohibits the dumping of high-level waste at sea. The exceptions to this prohibition are an emergency at sea or other emergencies that have no other feasible solutions. These emergency exceptions have been severely criticized, and the issue is not yet closed. The Convention also requires that the dumping of low-level radioactive waste be monitored by a national authority.

The use of the Antarctic ice sheet for high-level radioactive waste disposal is prohibited by the Antarctica Treaty of 1959. By this treaty, the member nations agree to police one another and to ensure that no one disposes of radioactive wastes in Antarctica. This treaty comes up for review in 1991, and it is possible that it may be modified at that time.

In 1976, President Ford proposed the establishment of multinationally controlled nuclear waste repositories under the auspices of the IAEA. This would be very advantageous to countries that do not have suitable waste repository sites and would complement the U.S. proposals for multinational nuclear fuel centers as a method of reducing nuclear weapons proliferation.

RESEARCH AND DEVELOPMENT

The principal research and development authority for both military and commercial radioactive waste was vested in the DOE by the Energy Reorganization Act. As a result of this, both the NRC and the EPA conduct only confirmatory research. Their studies are aimed at improving the quality of

regulations, not new and improved methods. Because the NRC recognizes the broader capability of DOE, it makes use of much of the data supplied by DOE. This procedure helps to isolate the NRC as an independent agency and ensures that it will not be asked to license a technology that it has developed.

The role of DOE in nuclear waste management is threefold in that it is manager, self-regulator of its management activities, and principal researcher for new and improved procedures. Along with these activities, the Atomic Energy Act included in its definition of research and development, the fundamental authorization to perform "demonstration projects." This definition gives DOE the authority to engage in all phases of radioactive waste activities from initial creation to ultimate disposal. The NRC regulatory controls do not seem to apply to the DOE in the areas of research and development nor to demonstrations involving transuranic wastes. Regardless of the absence of regulation, these demonstrations and other activities have far-reaching effects upon our national policies and managerial procedures regarding radioactive waste materials.

APPLICATION

Both the NRC and the DOE are party to a status report on the management of radioactive waste materials, issued in 1976 by the Federal Energy Resources Council. This report listed four requirements for the proper initiation of regulations:

- Reviews as mandated by the National Environmental Policy Act.
- Development and compliance with environmental standards

and criteria issued by the EPA.

- Compliance with the requirements and licensing criteria of the NRC.
- Provision of opportunities for public participation.

A prior document, the National Environmental Policy Act of 1969, is much more formidable in its requirements. This policy requires all federal agencies that recommend or report on proposed legislation, or any other federal action that affects the environment, to prepare an Environmental Impact Statement on each of these actions. A responsible official must make detailed statements on each of the following five areas in the Environmental Impact Statement:

- The environmental impact of the proposed action.
- The negative environmental effects that cannot be avoided if the proposal is implemented.
- Any alternatives to the proposed action.
- The effect of short-term use on the maintenance and enhancement of long-term productivity of the environment.
- Resources that would be irreversibly committed to the project.

Further, the statment must be prepared in consultation with all the federal agencies that have jurisdiction by law or by special expertise concerning the environmental impact, and it must include the statements of the federal agencies.

The Act (NEPA) does not require that the environment be unharmed, not does it require the rectification of any harm done. It does require that procedures be followed explicitly. The EPA, and often the Council on Environmental Quality, then review and comment upon all Environmental Impact Statements.

These reviews and comments, along with public opinion, often are important factors in whether or not proposals are funded or actions enjoined in court hearings.

THE ONCE-THROUGH FUEL CYCLE

At present, the United States has suspended the reprocessing of high-level wastes except for military waste, and wastes merely are stored. Whether or not commercial reprocessing will be resumed remains to be seen. Other countries continue to reprocess their materials.

Since the United States has suspended the reprocessing of commercial power reactor fuel (Figure 21-3-2), the storage of large numbers of spent fuel elements has become necessary. Such storage may continue indefinitely. At some future period, a decision concerning the final disposition of spent fuel elements will have to be made. One beneficial side effect of an extended storage period is a significant reduction in the highly radioactive, short-lived nuclides present in spent fuel.

Considering the large quantities of unreprocessed commerical fuel and the indefinite storage time, a much greater storage capacity will be required than that which already exists at the power reactor sites. Of necessity, this additional storage capacity will have to become part of the over-all waste management program, whether the program is commercial or is government operated.

Some of this needed storage capacity is available already at commercial reprocessing facilities not now scheduled to begin reprocessing operations. Such spent fuel capacity, as

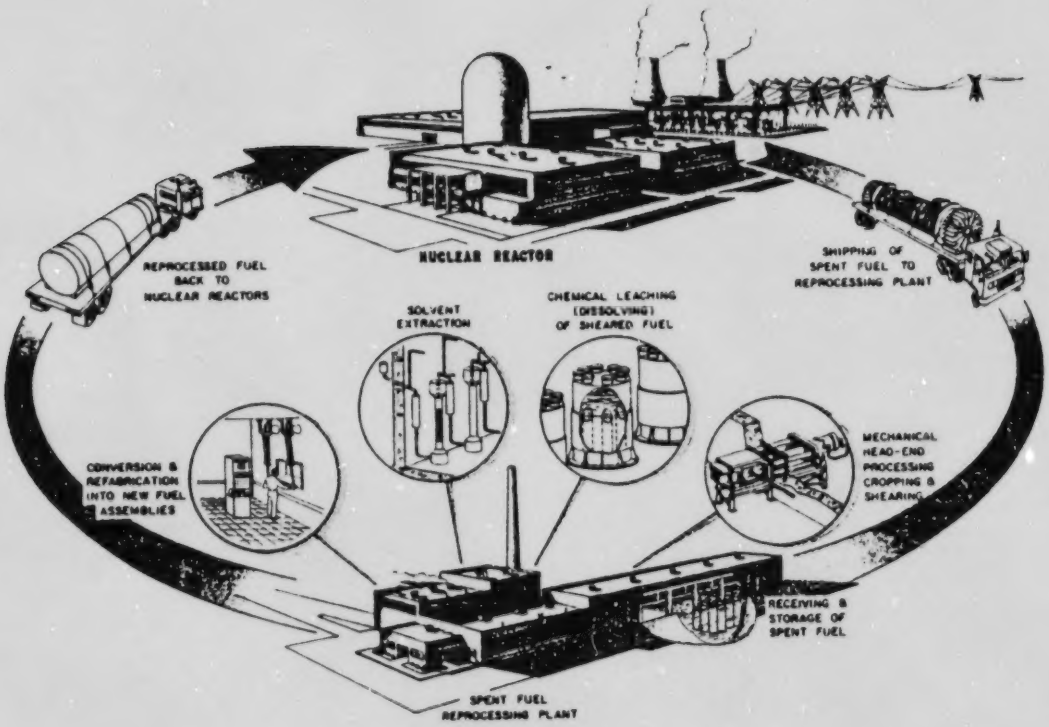

NUCLEAR REACTOR
REPROCESSED FUEL BACK TO NUCLEAR REACTORS
SHIPPING OF SPENT FUEL TO REPROCESSING PLANT
SOLVENT EXTRACTION
CHEMICAL LEACHING (DISSOLVING) OF SHEARED FUEL
CONVERSION & REFABRICATION INTO NEW FUEL ASSEMBLIES
MECHANICAL HEAD-END PROCESSING CROPPING & SHEARING
RECEIVING & STORAGE OF SPENT FUEL
SPENT FUEL REPROCESSING PLANT

Figure 21-3-2. Generalized nuclear fuel cycle of the United States prior to U.S. suspension of reprocessing.

well as additional capacity, may become a function of private industry, entirely separate from the governmental radioactive waste management program. Private industry may be reluctant, however, to provide this service in view of the uncertainty of final disposition.

WASTE MANAGEMENT AND REPROCESSING

The reprocessing of spent fuel recovers plutonium and uranium for use in light water reactors, in breeder reactors, or in military weapons. The waste from this reprocessing is

mostly high-level, although there is some transuranic waste. At present, no commercial reprocessing plants are in operation; however, DOE reprocesses spent fuel for military requirements.

For commercial nuclear power operations, the question remains: Is reprocessing desirable? If so, what are the consequences?

The first consideration is, of course, safety. While there is some hazard in the reprocessing procedures, the fact remains that processing can be performed safely. It does increase radiation hazard by concentrating the high-level waste into a smaller volume; however, at least three technologies already exist for the handling of this type of high-level waste.

The second consideration is economic. Nuclear fuel is expensive. Reprocessing cuts this cost to approximately two-thirds. Considering the present cost of energy, this must be evaluated in any policy determination. Research now is under way for the development of improved fuel burn-up in current light water reactors. When perfected, this improvement could result in cost reduction and extension of the uranium supply.

The third consideration is political. Demonstrations by the vocal minority of nuclear opponents do exert some pressure upon the political decision-making process.

MONITORING AND ENFORCEMENT

Both the NRC and DOE have the authority to monitor radioactive waste procedures and to enforce regulations. This au-

thority stems from the Atomic Energy Act of 1954. In this case, "monitoring" means review of the required reports, inspection of sites, and audit of inventories. Enforcemment is concerned with the punitive actions against those who violate regulations and licenses and with corrective measures, particularly safety and emergencies. The NRC regulations concerning these activities are very general, and the DOE has contractual conditions that require adherence to manual chapters that contain similar general requirements. In the case of the DOE, a contractor that does not comply with the requirements may have the contract rescinded, and the facility may be confiscated.

The actual legal weight of DOE manual chapters is not clear when compared with the NRC regulations published in the Code of Federal Regulations; however, the DOE considers the point moot since it can exert pressure on its managers through contracts.

Monitoring by the EPA can only occur at the property boundary since the EPA has no authority over processes. The EPA only can comment upon the condition of the environment at the facility boundary. The EPA has attempted, on occasion, to take authority for on-site activities, but legal decisions have held that the EPA has no authority over processes, but only over the condition of the environment after discharge of wastes.

The transportation of radioactive waste falls within the monitoring and enforcement authority of several agencies. General monitoring and enforcement falls to the DOT; however, maritime shipments are under the jurisdiction of the U.S. Coast Guard. The exception is maritime shipments by the DOE. If these shipments are accompanied by DOE personnel, they are exempt from Coast Guard regulations.

SUMMARY

Radioactive waste materials in the United States are produced from two sources: military and commercial activities. By far, the most toxic of these wastes are those produced by the military. The managerial requirements are comparable, although the costs, difficulties, and schedules are different.

Thus far, the federal government has adopted a primary technological perspective in its statements of fundamental policy goals. Isolation and containment is the current concept of safe management. Factors under study include interagency and international coordination, institutional stability, risk-cost analysis, public confidence, and consolidation of managerial responsibilities.

Achievement of radioactive waste policy goals under the present organization requires three separate functions. These are management, regulation, and research and development. There is a complicated division of the overall managerial responsibility between private industry and the federal government. Governmental responsibility falls to DOE and its contractors, while private industry responsibility goes to the licensees of the NRC and/or the agreement states. The short-term management of commercial high-level waste is the responsibility of the licensees; but in the long term, DOE takes the ultimate responsibility. The federal government has all the responsibility for military high-level radioactive waste. The plutonium production facilities that have high-level wastes are managed by DOE. Spent fuel elements from the nuclear Navy are the responsibility of the DOD until they are turned over to DOE. At the present time, the management of

commercial transuranic waste is the responsibility of the licensee in both the short and the long term. The NRC has, however, proposed regulations that would transfer the long-term responsibility to the DOE. The federal government has the entire responsibility for military transuranic waste.

A broad look at nuclear regulatory authority appears to be somewhat confusing. Most of the authority is vested in the NRC and DOE at the federal level, but there are regulatory claims made by other federal agencies, by state governments, and by certain international organizations. The EPA must be considered along with the NRC and DOE since it has the authority to set general environmental radiation exposure standards and to provide guidance for all of the federal agencies in establishing radiation standards.

The fundamental regulatory activity in radioactive waste operations is licensing and/or approval. The authority for the licensing of commercial high-level waste operations belongs entirely to the NRC. This authority apparently includes the DOE research and development storage facilities that receive commercial high-level waste materials.

The DOE gives short-term approval to the management of military high-level waste, and exercises monitoring and enforcement authority through contractual, rather than regulatory, activities. The NRC has the licensing authority for the long-term handling of military high-level waste. The two exceptions to this are DOE research and development facilities and DOE facilities that were in existence before the Energy Reorganization Act of 1974.

The DOE can approve its own site selection, construction, and the operation of its research and development facilities. The NRC, however, retains the authority to license DOE demon-

stration repositories for high-level waste materials if such are to be used in the demonstration.

The NRC holds the regulatory authority for transuranic waste materials; however, in some instances, this authority has been relinquished, either wholly or in part, to the NRC Agreement States. The NRC has proposed regulations that would require all short-term managers to turn over their transuranic waste to DOE for long-term management.

The DOT is responsible for the safe transport of radioactive materials. A cooperative agreement between the DOT and the AEC, which now applies to the DOE and the NRC, divides the responsibility for the establishment of packaging and handling standards. Licensing responsibility for the transportation of radioactive waste materials remains with the nuclear agencies, although the agencies have agreed to enforce the applicable DOT standards as well as their own.

Federal authority generally preempts the authority of the states in radioactive waste management operations. By existing laws, the states may regulate only the nonradiological portions of these activities, and they must not interfere with the regulation and promotion of nuclear energy by the federal government. Both the states and the private citizen, however, are allowed input into the federal decision-making process.

The use of the oceans as a radioactive waste management option presently would involve both national and international agencies. Presently, permits for the dumping of transuranic waste materials at sea would have to be issued by the EPA, although the United States does not dump transuranic waste in the ocean. Likewise, the dumping of high-level radioactive waste in the ocean is prohibited. The EPA also claims permit-

issuing authority over deep seabed burial, but this is open to dispute. Internationally, the United States is party to several formal agreements, but they place no unreasonable restraints on the U.S. radioactive waste policy. There is no effective international monitoring or enforcement agency at the present time. Additionally, the Antarctic ice sheet does not provide an option for the disposal of radioactive waste.

Radioactive waste management research and development is controlled almost totally by the DOE, and research by the EPA and NRC is only confirmatory in their area of interest.

The relationship between the four major government agencies can be summarized as follows:

- The EPA establishes environmental standards (40 CFR, Part 190).
- The NRC establishes rules and regulations that implement EPA standards and the Atomic Energy Act of 1954, as amended. (Refer to the below description of the DOT.)
- The DOE is responsible for providing and operating a federal repository in accordance with NRC regulations.
- The DOT establishes transport regulations; the NRC establishes packaging regulations and monitors some shipments.

Since the present U.S. policy is not to reprocess spent fuel commercially, there is a managerial problem concerning storage.

EXERCISES

1. List two federal agencies that hold responsibility for the management of military high-level radioactive waste materials.
2. Who has the managerial responsibilities for commercial high-level radioactive waste?
3. Which federal agencies have the regulatory jurisdiction over transuranic waste materials?
4. Which agencies hold regulatory jurisdiction over the transportation of radioactive waste materials? How do these agencies interact?
5. List the federal agencies that have authority for the monitoring and enforcement of radioactive waste procedures, including their methods of enforcement.

MATERIALS

1 copy of the "Memoranda of Understanding" section of the Commission Notices of Title 10, Chapter 1, of the Code of Federal Regulations.

1 copy of Title 10, Chapter 1, Code of Federal Regulations, Part 51.

EXPLANATION:

Familiarity with the rules as written by the rule maker is important in order to prevent distortion by anyone who would interpret the rules incorrectly.

1. Locate the section that relates to accidents and incidents in the "Memoranda of Understanding" concerned with the Transportation of Radioactive Materials, in Title 10, Chapter 1, Code of Federal Regulations; and discuss in Data Table 21-3-1 which agency has lead responsibility and why:
   - In case of an accident in transit.
   - If a leaking cask is discovered after delivery.

2. Locate the section that relates to the Requirements for Environmental Impact Statements, Negative Declarations, and Impact Appraisal in Part 51 of Title 10, Chapter 1, Code of Federal Regulations; and using Data Table 21-3-2, prepare a list of actions that require the preparation of an Environmental Impact Statement.

DATA TABLES

DATA TABLE 21-3-1

Lead Agency	Accident in Transit	Leak after Delivery

DATA TABLE 21-3-2

ACTIONS

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

REFERENCE MATERIALS

IAEA. Radioactive Waste Disposal into the Ground. New York: Unipub, Inc.

The Management of Radioactive Wastes Produced by Radioisotope Users. New York: Unipub, Inc.

Principles for Establishing Limits for the Release of Radioactive Materials into the Environment. New York: Unipub, Inc.

United States Nuclear Regulatory Commission. Rules and Regulations: Title 10 Code of Federal Regulations. Washington, DC: Superintendent of Documents, Government Printing Office, Latest issue with updated Supplements.

1. List the goals of the NRC and the DOE in regulating the disposition of radioactive waste materials.

2. Which federal agency or agencies has jurisdiction over spent fuel elements from commercial nuclear reactors?

3. List two international agreements that regulate the disposition of radioactive wastes.

4. Which agencies are responsible for the monitoring and enforcement of regulations concerned with the disposition of radioactive wastes?

5. Chemical and radiological analysis of a sample of a radioactive waste material indicates that the isotopic content includes 29 mCi per liter of ^{239}Pu, and the combined activities of all the radioisotopes present are analogous to a single-element activity of 37 mCi per liter. Should this material be considered high-level or transuranic waste? Why should it be so considered?

NUCLEAR TECHNOLOGY

MODULE 21-4

MEASUREMENT OF EXTERNAL RADIOACTIVE CONTAMINATION

RADIOACTIVE MATERIALS DISPOSAL
AND MANAGEMENT

COURSE 21

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

COURSE 21 RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

MODULE 21-1 Radioactive Waste Disposal Procedures

MODULE 21-2 Routine Sampling of Radioactive Waste

MODULE 21-3 Radioactive Waste Disposal Regulations

MODULE 21-4 Measurement of External Radioactive Contamination

MODULE 21-5 Regulations for Transportation of Radioactive Materials

MODULE 21-6 Packaging and Monitoring of Radioactive Materials for Shipment

MODULE 21-7 Leak Tests of Sealed Radioactive Sources

Copyright© 1980

Center for Occupational Research and Development, Incorporated
4800 Lakewood Drive, Waco, Texas 76710

Reproduction or publication of the content in any manner, without the express permission of the Center for Occupational Research and Development, Incorporated, is prohibited. No liability is assumed with respect to the use of the information herein.

INTRODUCTION

Regulations that affect the transportation of radioactive waste material have been issued by the U.S. Department of Transportation (DOT), the U.S. Nuclear Regulatory Commission (NRC), and individual states. Precise knowledge of the external radiation field around the waste container and the amount of surface contamination on the container is required in order to comply with these regulations.

MODULE PREREQUISITES

The student should have successfully completed modules 21-1, 21-2, and 21-3 in this course and course II, "Radiation Detection and Measurement."

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Survey radioactive waste containers in order to determine the radiation field strength around the container.
2. List the appropriate action to be taken when given the intensity of the radiation field around a waste container.

3. Perform smear tests to determine whether contamination found on the outside of a waste container is fixed or loose.
4. Determine if the radiations from a smear test are alpha, beta, or gamma radiations or a combination of radiations.
5. Select the appropriate instrument when given a choice of three calibrated instruments and asked to count a sample for a specific alpha, beta, and/or gamma emitter.
6. Given the activity level and other needed information, list the options for corrective action if a smear test does not meet specifications.

When radioactive waste materials are placed into a container, the shielding of the container may or may not provide compliance with regulations. Additionally, the external surface of the container may become contaminated with radioactive material. The area around the container, therefore, must be surveyed and the container subjected to wipe tests to determine whether or not the container may be shipped.

IDENTIFICATION OF THE RADIOACTIVE MATERIAL

Often, both the identity and intensity of the radioactive materials in a particular waste are known, although regrettably, this is not always the case. When the identity of the radionuclide is not known, the first step in the survey of a container of radioactive waste material should be identification of the radioactive species present. Identification may be accomplished by either a sample obtained for laboratory analysis or by the use of a portable gamma X-ray spectrometer. Figure 21-4-1 depicts a typical 100-channel gamma spectrometer.

Figure 21-4-2 shows the gamma spectrum of a single radionuclide. Figure 21-4-3 demonstrates the gamma spectrum of a mixture of three radionuclides.

After the radioactive isotopes present have been identified, the transport group identification must be ascertained. The transport group is any one of seven groups into

which radionuclides are classified according to their radiotoxicity and potential hazard in transportation. This classification can be found in 49CFR170.389(h) and 49CFR170.390(a). The Appendix, beginning on page 24 of this module, provides a series of tables for use in the classification of radioisotopes by transport group.

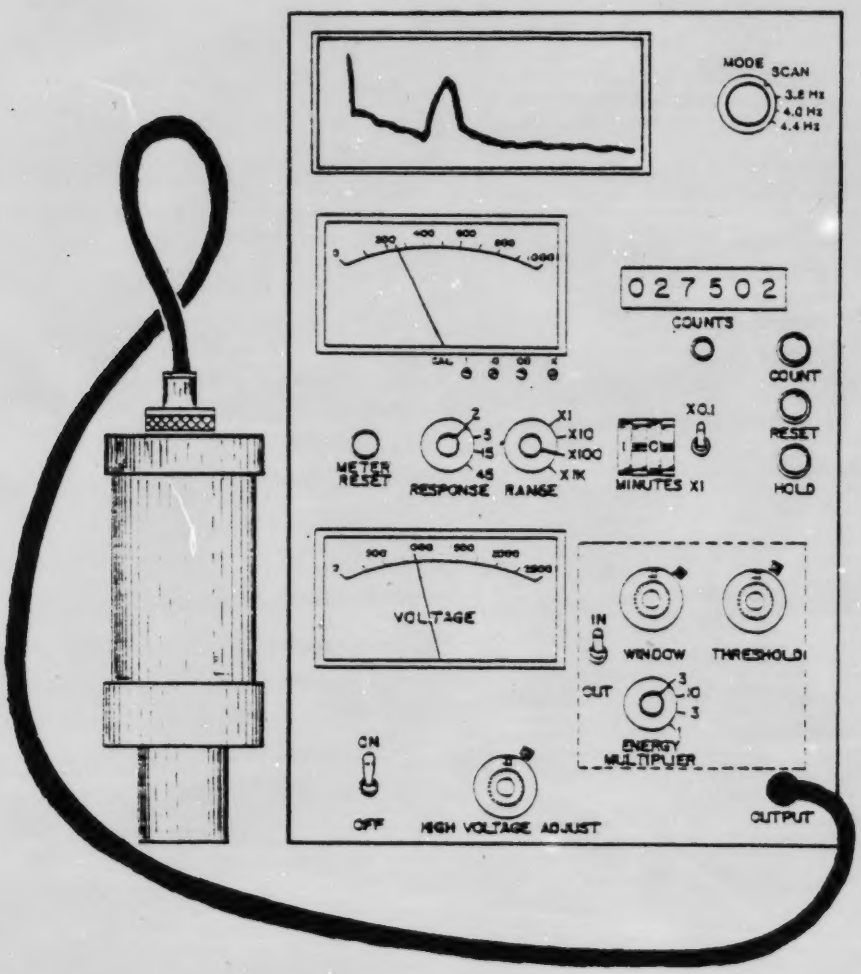


Figure 21-4-1. A portable gamma-ray spectrometer.

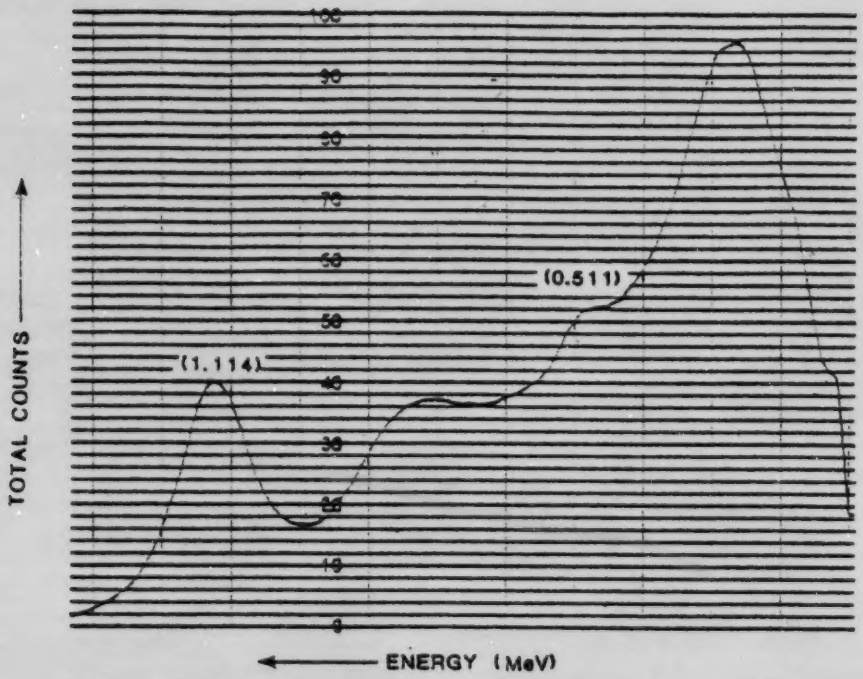


Figure 21-4-2. The gamma spectrum of ^{65}Zn.

Externally-contaminated nonradioactive materials may be considered as low-specific-activity sources if the radioactive contamination is not readily dispersable and if the surface contamination averaged over one square meter does not exceed 0.1 microcurie per square centimeter for Group I radionuclides or 1 microcurie per square centimeter for other radionuclides.

External contamination that is not fixed is that in which the contaminant can be removed readily in measurable quantities by the wiping of the contaminated surface with absorbent material. Unfixed external contamination has the following limitations:

- 10 pCi (picocuries) of beta-gamma emitter per square centimeter, and 1 pCi of alpha emitter per square centimeter for all contaminants except natural or depleted uranium or natural thorium.
- 100 pCi of beta-gamma emitter per square centimeter, and 10 pCi of alpha emitter per square centimeter for natural or depleted uranium or natural thorium.

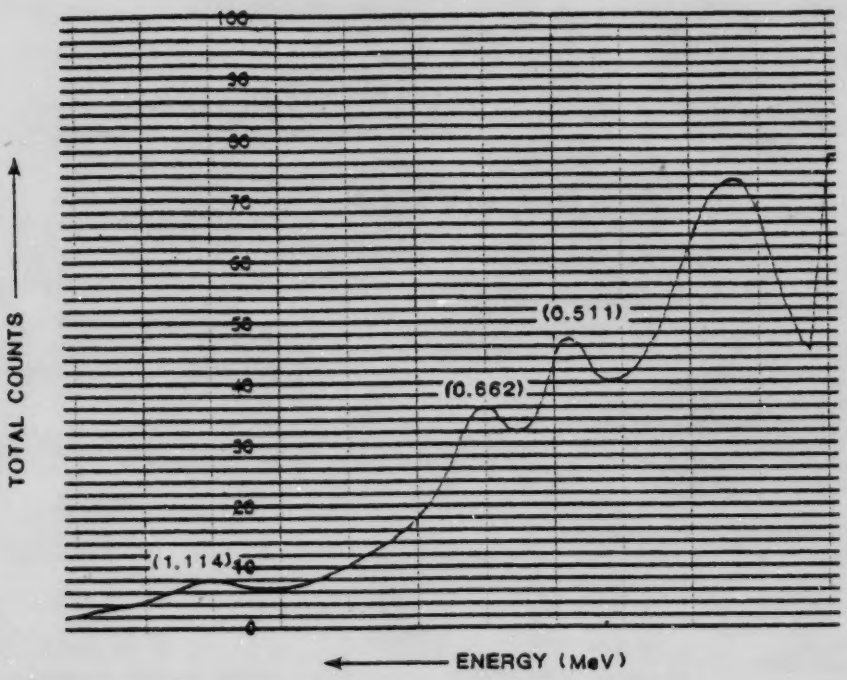


Figure 21-4-3. The gamma spectrum of a mixture of radioisotopes.

EXTERNAL RADIATION FIELD

The external radiation field around a radioactive waste container establishes the transport index, which, in turn, designates the method of transport to be used by the carrier. The transport index is the highest radiation dose rate in millirem per hour at three feet from any accessible surface of the package.

Containers that are to be shipped by any method other than a closed vehicle assigned for the sole use of the consignor, and unloaded by the consignee, must be shielded in such a manner that the dose rate at any exposed surface of the container is a maximum of 200 millirem per hour. The dose rate at a distance of three feet from any exposed surface of the container must not exceed 10 millirem per hour. Containers of radioactive waste material that are shipped in sole-use, closed transport have somewhat higher limitations. Their external radiation field must not exceed 1000 millirem per hour at three feet from the external surface of the package; 200 millirem per hour at any point on the external surface of the vehicle; 10 millirem per hour at six feet from the external surface of the vehicle; and 2 millirem per hour in any normally-occupied position in the car or vehicle.

SURVEY OF THE EXTERNAL RADIATION FIELD

Initial survey of the radiation field around a container of radioactive waste material is conducted best with an ion chamber survey meter. Care should be exercised in se-

lection of the instrument, to ensure that there is sufficient instrument sensitivity to provide an accurate determination of field strength. Figure 21-4-4 depicts a typical ion chamber survey instrument for use in the survey of radiation fields.

Figure 21-4-4,
A typical ion chamber survey instrument.

Some type of gaging device should be used to maintain a three-foot distance from the waste container. Innovative technicians may even construct a device to be affixed rigidly to the survey instrument.

Remember that the field survey should be conducted on each individual container, located well away from other containers of radioactive waste. This practice will assure that

the radiation being measured is that emanating from the container in question.

NOTE: BE SURE TO SURVEY THE TOP AND BOTTOM OF THE CONTAINER.

A container of radioactive waste material that has an external radiation field that exceeds 10 millirem per hour requires one of three alternatives for disposition of the container.

The first alternative is decontamination. There is a possibility that the outer surfaces of a container of radioactive waste that exhibits an external radiation field greater than 10 millirem per hour may have become contaminated while the container was being filled. If such contamination has occurred, the logical choice by the technician is to decontaminate the surface and to determine if this procedure reduces the field to within acceptable limits. After decontamination, if the field is still above the 10 millirem/hour limit, the waste material either will have to be repackaged or it may be shipped in a sole-use, closed vehicle, assuming that the external field does not exceed 1000 millirem/hour.

The second alternative, when the external radiation field exceeds 10 millirem per hour, is the removal of some of the radioactive material from the container. This is, in effect, repackaging. An administrative choice must be made considering both economics and compliance, with the compliance feature weighing most heavily.

The third option is shipment of the container in a sole-use, closed vehicle, in which case, the three-foot radiation field must not exceed 1000 millirem/hour. If it does, the material must be repackaged.

THE SURVEYING OF SURFACE ACTIVITY

The second survey required of a container of radioactive waste material involves surface contact. This survey may be conducted with either an ion chamber or with a Geiger-Mueller (GM) type instrument, although the ion chamber is preferable. During the performance of this survey is an opportune time for the technician to locate sites of abnormally high activity for a contamination survey.

The radiation dose at the surface of the container must not exceed 200 millirem per hour if the container is to be shipped by anything other than a sole-use closed vehicle. If it does exceed this amount, there are two options.

As the first option, the external container surface can be checked for surface contamination. If contamination is found, and if the container can be decontaminated to bring the contact radiation level within acceptable limits, the container may be shipped.

The second option occurs either when no external surface contamination can be found which indicates that all activity is coming from within, or when the container cannot be decontaminated. When this occurs, the radioactive waste material must be repackaged before shipment.

SURFACE CONTAMINATION SURVEY

The techniques involved in the surface-contamination survey are identical to those used in the standard smear, or wipe, survey. The surfaces of the container are sampled statistically and specifically for removable surface contamination.

Statistical samples should be taken from the areas of most probable contamination. These areas include the sides of the container, extending approximately six inches around the opening, and any ridges or protrusions extending from the container below the opening.

Smears taken for a contamination survey may be either wet or dry. Dry smears are used more often, although the wet-smear technique is preferred for accuracy. The smear may be taken with either paper or cloth smear blanks, but care must be taken to ensure that the material is not torn. Smear samples for contamination survey must be counted for both alpha and beta-gamma activity. This counting can be accomplished by use of a proportional counter or by use of an alpha counter combined with a Geiger-Mueller counter. Figures 21-4-5 and 21-4-6 depict typical alpha and beta-gamma counters, respectively. If the isotope or isotopes involved are known, the techniques are simplified greatly.

The contaminant limitations, as previously mentioned, are as follows:

- 10 pCi of beta-gamma emitter and 1 pCi of alpha emitter per square centimeter for all contaminates except natural or depleted uranium or natural thorium.
- 100 pCi of beta-gamma emitter and 10 pCi of alpha emitter per square centimeter for natural or deleted uranium or natural thorium.

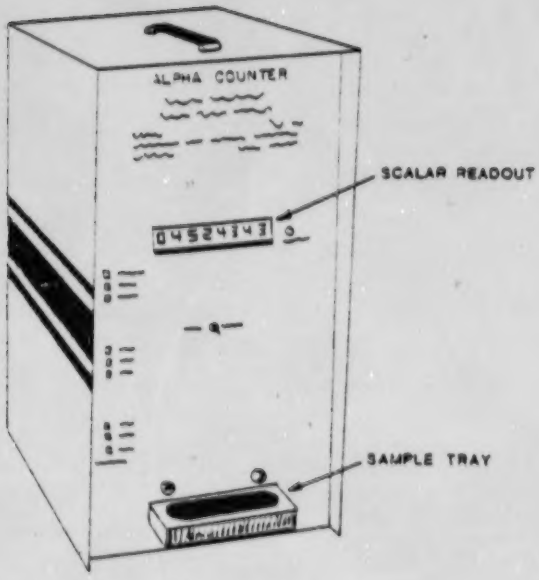


Figure 21-4-5. An alpha scintillation counter.

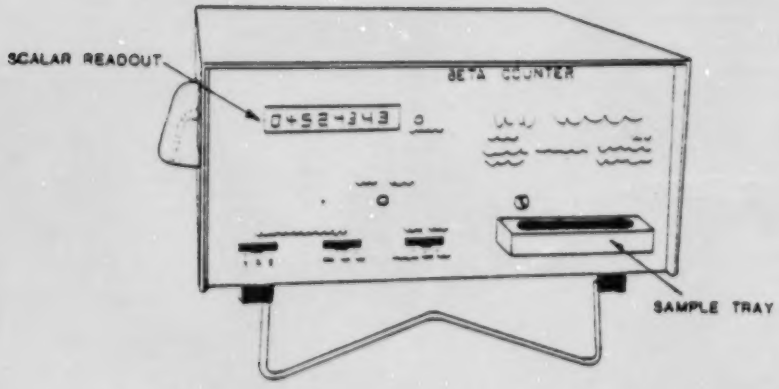


Figure 21-4-6. A beta-gamma counting system.

BACKGROUND AND DESCRIPTION OF SMEAR TESTING

When a surface has become contaminated with a radioactive material, the amount of activity that will rub off the surface onto the hands or clothing of personnel working around that surface should be determined.

A smear test can be made to estimate the amount of removable activity. This is accomplished by firmly wiping a filter disk across the contaminated surface, encompassing an area of approximately 100 cm^2. The filter disc is then mounted and counted, usually in a beta counting system. If alpha activity is suspected, however, it should be counted in an alpha counting system, as well. From the count rates thus obtained, the activity on the filter disc is calculated, by use of the efficiency of the counting system for the particular isotope involved. In the beta counting system, if the identity of the particular isotope is unknown, the sample usually is counted as if it were cobalt-60.

The exception to this procedure occurs when tritium is a possible contaminant. Suspected tritium contamination should be smeared with alcohol wipes or some other solvent that is compatible with liquid scintillation counting. Then the entire wipe should be dissolved in the scintillation cocktail for counting.

PROCEDURE FOR THE COLLECTION OF ROUTINE SMEARS

The establishment of a basis for comparison among different smears requires that the same amount of area be sampled each time. Health physicists have agreed upon 100

square centimeters as the "standard" sample area. Smears are prepared as follows:

1. Obtain a series of clean smear blanks in record holders.
2. Check the smears and holders to ensure that they are numbered sequentially.
3. Place the linenized surface of the first smear into contact with the suspected contaminated surface.
4. Wipe the suspect surface with the smear, using firm contact, covering 100 square centimeters (approximately 4" x 4").
5. Close the smear holder in order that the activity of the smear will not be changed.
6. Repeat the procedure, using sequentially-numbered smear blanks until all suspect areas have been wiped.

PROCEDURE FOR THE DETERMINATION OF SMEAR ACTIVITY

The determination of the activity on each of the smears involves calculations as well as measurement:

1. Calculate the maximum permissible activity in counts per minute based upon the allowable activity and the efficiency of the counting system.
2. Estimate the background activity by placing an uncontaminated smear disc in a planchet and counting it in the system for three minutes.
3. Using the calculated maximum permissible counts per minute and the estimated background activity, determine the required background counting time by referring to the Radiological Health Handbook.

4. Using the same information, determine the most efficient counting time for a sample that contains the maximum permissible activity.
5. Determine the actual background rate by counting the uncontaminated smear disc for the required length of time.
6. Count each smear sample for the time required for the maximum permissible activity.
7. Calculate the net sample count rate of the smear by subtracting the background count rate from the smear count rate.
8. Calculate the activity of the smear from the relationship expressed by Equation 21-4-1:

$$\text{Activity (pCi)} = \frac{\text{Sample Count Rate (cpm)}}{\text{Counter efficiency (cpm/dpm)}} \times \frac{1 \text{ pCi}}{2.22 \text{ dpm}}$$

Equation 21-4-1
(Equation = Eq.)

9. Calculate the activity per square centimeter by dividing the activity by 100 square centimeters.

NONCOMPLIANCE SMEARS

Three alternatives are allowed for a smear sample that does not comply with the maximum limits. The first of these is the taking of another sample, with particular attention paid to the sampling technique.

The second alternative is the decontamination of the area in question. Decontamination must be followed by resampling of the area in question.

The third alternative is the repackaging of the material with the original package considered as waste material. Usually, this alternative is a last resort.

The following example illustrates the calculation of smear activity in picocuries per square centimeter.

EXAMPLE

Given: A smear exhibits a count rate of 100 counts per minute with a background rate of 12 counts per minute. The ^{60}Co efficiency of the counting system is 0.37. The smear area is 100 square centimeters.

Find: The activity of the smear in picocuries per square centimeter.

Solution: Calculations:

Net Count Rate –

$$\text{Count rate} - \text{background count rate} = \text{net count rate}$$

$$100 \text{ cpm} - 12 \text{ cpm} = 88 \text{ cpm}.$$

Smear Activity –

$$\frac{\text{net count rate}}{\text{efficiency } (^{60}Co)} \times \frac{1 \text{ pCi}}{2.22 \text{ dpm}} = \text{activity}.$$

$$\frac{88 \text{ cpm}}{0.37 \text{ cpm/dm}} \times \frac{1 \text{ pCi}}{2.22 \text{ dpm}} = 107.1 \text{ pCi}.$$

Activity Per Square Centimeter –

Activity/100 cm^2 = A/cm^2

107.1 pCi/100 cm^2 = 1.07 pCi/cm^2.

EXERCISES

1. Use the tables from 49CFR (listed in Appendix) to find the transport group for the following listed radioisotopes:
   - Cobalt-60.
   - Cesium-137.
   - Strontium-90.
   - Mixed fission products.
   - Polonium-210.
   - Radium-226.
   - Iodine-131.
   - Carbon-14.
   - Hydrogen-3.
   - Plutonium-239.
2. A smear sample from a barrel of radioactive waste material exhibits no alpha activity and a net beta-gamma count rate of 391 counts per minute in a beta-gamma counter having a ^{60}Co efficiency of 0.47. What is the activity at the smear site? What should be the disposition of the barrel of radioactive materials?

MATERIALS

Container of radioactive waste materials packaged for shipment (may be simulated). The external surface of the container should be contaminated with the radioisotope in the container.
Portable gamma scintillation spectrometer.
Alpha scintillation counter.
Beta counter.
Package of smear discs.
Package of smear disc holders.
Planchets to fit smear discs.
Charts for the identification of gamma spectra.

PROCEDURES

IDENTIFICATION OF A RADIOISOTOPE BY ITS GAMMA SPECTRUM

CALIBRATION OF THE GAMMA SPECTROMETER

1. Display the gamma spectrum of a sample of ^{137}Cs (0.662 MeV).
2. Determine and record in Data Table 21-4-1 the channel number of the 0.662-MeV photopeak.
3. Display the gamma spectrum of a sample of ^{65}Zn (1.114-MeV).
4. Determine and record the channel number of the 1.114-MeV photopeak.

5. Prepare a plot on linear graph paper of photopeak energy versus channel number. Use the graph in Figure 21-4-7, "Channel energy calibration."

COLLECTION OF THE UNKNOWN GAMMA SPECTRUM

1. Place the gamma scintillation detector near the unidentified gamma emitter – within a few centimeters if possible.
2. Collect the gamma spectrum at least enough to half fill the memory storage of the spectrometer.

IDENTIFICATION OF THE UNKNOWN SPECTRUM

1. Display the gamma spectrum on the spectrometer display.
2. Identify and record the channel number of all channels containing photopeaks. Use Data Table 21-4-2.
3. Use the "Channel energy calibration" graph Figure 21-4-7 to determine the energy of the gamma photons that produce each photopeak.
4. Compare these photon energies with those listed in a chart of radionuclides listed according to gamma photon energies in order to identify the radionuclides present.

COLLECTION AND COUNTING OF A SMEAR SAMPLE

1. Obtain a clean "smear" disc in a smear record holder.
2. Place the clean, linenized surface of the smear disc into contact with the suspected contaminated surface.

3. Place the first two fingers of your hand on the back of the smear record holder, near the center of the smear disc.
4. Using firm pressure of the finger tips, wipe the smear disc over 100 square centimeters of the suspected contaminated surface.
5. Close the smear holder to prevent the activity of the smear from being changed.
6. Place a clean smear disc in a clean planchet, and count the background with a beta counter for three minutes.
7. Record the background total count and count rate in Data Table 21-4-3.
8. Place the contaminated smear disc in a clean planchet, with the contaminated side toward the detector.
9. Count the contaminated smear disc in the beta counter for four minutes.
10. Record the total count and the count rate in Data Table 21-4-3.
11. Subtract the background count rate from the smear count rate to obtain the net count rate. Record this and the following values in Data Table 21-4-4.
12. Divide the net count rate by efficiency factor to obtain the activity in dpm.
13. Divide the activity in dpm by 2.22 dpm to obtain the activity in picocuries.
14. Since the area wiped was 100 cm^2, the activity in picocuries should be divided by 100 to yield activity in picocuries per square centimeter.

DATA TABLE 21-4-1

Isotope	Energy	Channel
^{137}Cs	0.662	
^{65}Zn	1.114	

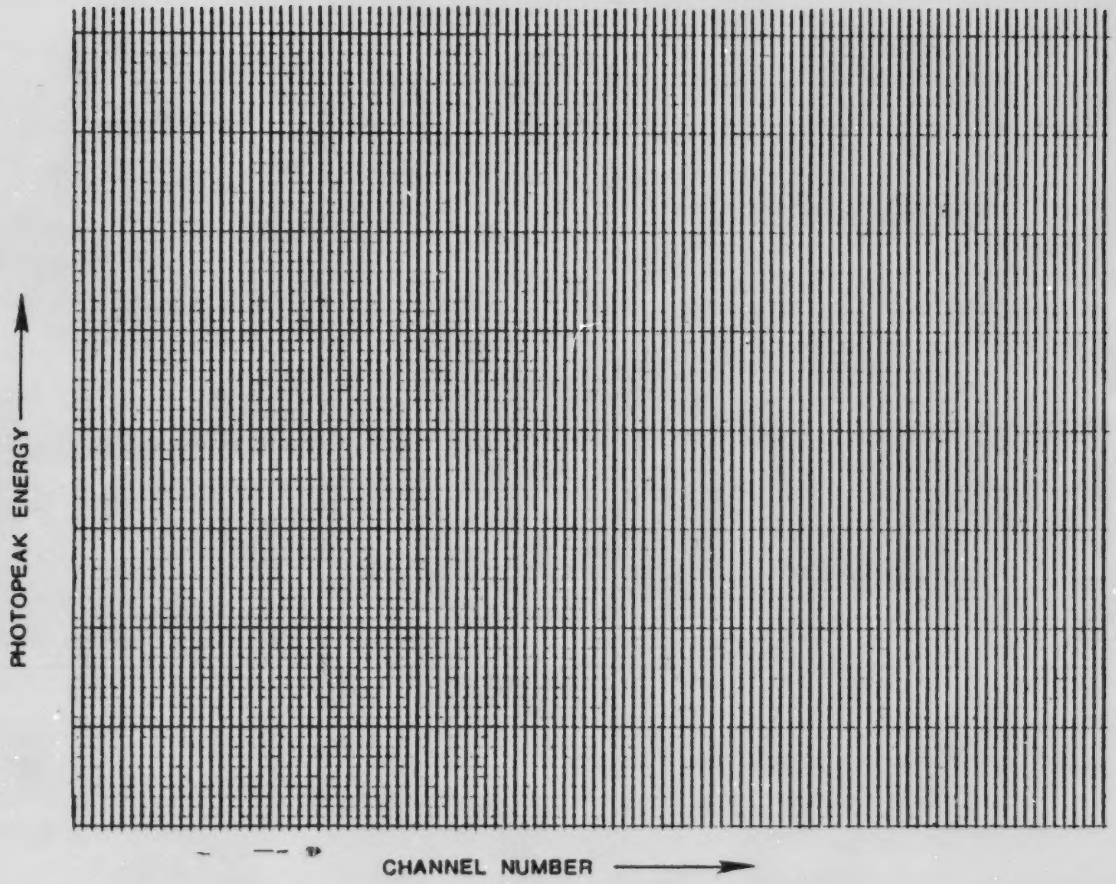


Figure 21-4-7. Channel energy calibration.

DATA TABLE 21-4-2

UNKNOWN SPECTRUM CHANNEL ENERGIES

Channel No.								
Energy MeV								

DATA TABLE 21-4-3
SMEAR SAMPLE COUNT

	Count Time Minutes	Total Count	Count per Minute
Background			
Smear Sample			

DATA TABLE 21-4-4

RESULTS

Smear Number	Corrected Count Rate	^{60}Co Efficiency	Total Activity	Area Activity pCi/cm^2

REFERENCE MATERIALS

Cember, N. Introduction to Health Physics. Exeter, Great Britain: Pergamon Press, Ltd., 1969.

Metcalf, T.B. Radiation Spectra of Radionuclides 1976. Park Ridge, NJ: Noyes Data Corporation, 1976.

U.S. Department of Health, Education, and Welfare. Radiological Health Handbook. Washington, D.C.: U.S. Government Printing Office, 1974.

U.S. Department of Transportation. Code of Federal Regulations, Title 49, Parts 100-199. Washington, D.C.: U.S. Government Printing Office, 1976.

See sections 170.389 and 170.390.

APPENDIX

Classification of Radionuclides into Transport Groups

APPENDIX A

Classification of Radionuclides into Transport Groups

Symbol	Radionuclide	Group	Symbol	Radionuclide	Group
A	Argon-37	VI	Br	Bromine-82	IV
	Argon-41	II			
	Argon-41 (uncompressed)(a)	V	C	Carbon-14	IV
			Ca	Calcium-45	IV
Ac	Actinium-227	I		Calcium-47	IV
	Actinium-228	I			
			Cd	Cadmium-109	IV
Ag	Silver-105	IV		Cadmium-115m	III
	Silver-110m	III		Cadmium-115	IV
	Silver-111	IV			
			Ce	Cerium-141	IV
Am	Americium-241	I		Cerium-143	IV
	Americium-243	I		Cerium-144	III
As	Arsenic-73	IV	Cf	Californium-249	I
	Arsenic-74	IV		Californium-250	I
	Arsenic-76	IV		Californium-252	I
	Arsenic-77	IV			
			Cl	Chlorine-36	III
At	Astatine-211	III		Chlorine-38	IV
Au	Gold-193	III	Cm	Curium-242	I
	Gold-194	III		Curium-243	I
	Gold-195	III		Curium-244	I
	Gold-196	IV		Curium-245	I
	Gold-198	IV		Curium-246	I
	Gold-199	IV			
			Co	Cobalt-56	III
Ba	Barium-131	IV		Cobalt-57	IV
	Barium-133	II		Cobalt-58m	IV
	Barium-140	III		Cobalt-58	IV
				Cobalt-60	III
Be	Beryllium-7	IV			
			Cr	Chromium-51	IV
Bi	Bismuth-206	IV			
	Bismuth-207	III	Cs	Cesium-131	IV
	Bismuth-210(Ra.E)	II		Cesium-134m	III
	Bismuth-212	III		Cesium-134	III
				Cesium-135	IV
Bk	Berkelium-249	I		Cesium-136	IV
				Cesium-137	III

(a) Uncompressed shall mean at a pressure not exceeding one atmosphere absolute at 0°C. and mean sea level.

Classification of Radionuclides into Transport Groups (continued)

Symbol	Radionculide	Group	Symbol	Radionculide	Group
Cu	Copper-64	IV	I	Iodine-134	IV
				Iodine-135	IV
Dy	Dysprosium-154	III			
	Dysprosium-165	IV	In	Indium-113m	IV
	Dysprosium-166	IV		Indium-114m	III
				Indium-115m	IV
Er	Erbium-169	IV		Indium-115	IV
	Erbium-171	IV			
			Ir	Iridium-190	IV
Eu	Europium-150	III		Iridium-192	III
	Europium-152	III		Iridium-194	IV
	Europium-152m	IV			
	Europium-154	II	K	Potassium-42	IV
	Europium-155	IV		Potassium-43	III
F	Fluorine-18	IV	Kr	Krypton-85m	III
				Krypton-85m (uncompressed) (a)	V
Fe	Iron-55	IV			
	Iron-59	IV		Krypton-85	III
				Krypton-85 (uncompressed) (a)	VI
Ga	Gallium-67	III			
	Gallium-72	IV		Krypton-87	II
				Krypton-87 (uncompressed) (a)	V
Gd	Gadolinium-153	IV			
	Gadolinium-159	IV			
			La	Lanthanum-140	IV
Ge	Germanium-71	IV			
			Lu	Lutetium-172	III
H	Hydrogen-3			Lutetium-177	IV
	(see T-Tritium)				
			M.f.p.	Mixed fission	II
Hf	Hafnium-181	IV		products	
Hg	Mercury-197m	IV	Mg	Magnesium-28	III
	Mercury-197	IV			
	Mercury-203	IV	Mn	Manganese-52	IV
				Manganese-54	IV
Ho	Holmium-166	IV		Manganese-56	IV
I	Iodine-124	III	Mo	Molybdenum-99	IV
	Iodine-125	III			
	Iodine-126	III	Na	Sodium-22	III
	Iodine-129	III		Sodium-24	IV
	Iodine-131	III			
	Iodine-132	IV			
	Iodine-133	III			

Classification of Radionuclides into Transport Groups (continued)

Symbol	Radionuclide	Group	Symbol	Radionuclide	Group
Nb	Niobium-93m	IV	Pt	Platium-191	IV
	Niobium-95	IV		Platium-193	IV
	Niobium-97	IV		Platium-193m	IV
				Platium-197m	IV
Nd	Neodymium-147	IV		Platium-197	IV
	Neodymium-149	IV			
			Pu	Plutonium-238	I
Ni	Nickel-56	III		Plutonium-239	I
	Nickel-59	IV		Plutonium-240	I
	Nickel-63	IV		Plutonium-241	I
	Nickel-65	IV		Plutonium-242	I
Np	Neptunium-237	I	Ra	Radium-223	II
	Neptunium-239	I		Radium-224	II
				Radium-226	I
Os	Osmium-185	IV		Radium-228	I
	Osmium-191m	IV			
	Osmium-191	IV	Rb	Rubidium-86	IV
	Osmium-193	IV		Rubidium-87	IV
				Rubidium natural	IV
P	Phosphorus-32	IV			
			Re	Rhenium-183	IV
Pa	Protactinium-230	I		Rhenium-186	IV
	Protactinium-231	I		Rhenium-187	IV
	Protactinium-233	II		Rhenium-188	IV
				Rhenium natural	IV
Pb	Lead-203	IV			
	Lead-210	II	Rh	Rhodium-103m	IV
	Lead-212	II		Rhodium-105	IV
Pd	Palladium-103	IV	Rn	Radon-220	IV
	Palladium-109	IV		Radon-222	II
Pm	Promethium-147	IV	Ru	Ruthenium-97	IV
	Promethium-149	IV		Ruthenium-103	IV
				Ruthenium-105	IV
Po	Polonium-210	I		Ruthenium-106	III
Pr	Praseodymium-142	IV	S	Sulphur-35	IV
	Praseodymium-143	IV			

Classification of Radionuclides into Transport Groups (continued)

Symbol	Radionuclide	Group	Symbol	Radionuclide	Group
Sb	Antimony-122	IV	Tc	Technetium-96m	IV
	Antimony-124	III		Technetium-96	IV
	Antimony-125	III		Technetium-97m	IV
				Technetium-97	IV
Sc	Scandium-46	III		Technetium-99m	IV
	Scandium-47	IV		Technetium-99	IV
	Scandium-48	IV			
			Te	Tellurium-125m	IV
Se	Selenium-75	IV		Tellurium-127m	IV
				Tellurium-127	IV
Si	Silicon-31	IV		Tellurium-129m	III
				Tellurium-129	IV
Sm	Samarium-145	III		Tellurium-131m	III
	Samarium-147	III		Tellurium-132	IV
	Samarium-151	IV			
	Samarium-153	IV	Th	Thorium-227	II
				Thorium-228	I
Sn	Tin-113	IV		Thorium-230	I
	Tin-117m	III		Thorium-231	I
	Tin-121	III		Thorium-232	III
	Tin-125	IV		Thorium-234	II
				Thorium natural	III
Sr	Strontium-83m	IV			
	Strontium-85	IV	Tl	Thallium-200	IV
	Strontium-89	III		Thallium-201	IV
	Strontium-90	II		Thallium-202	IV
	Strontium-91	III		Thallium-204	III
	Strontium-92	IV			
			Tm	Thulium-168	III
T	Tritium	IV		Thulium-170	III
	Tritium-activated luminous paint, tritium gas, or adsorbed on a solid carrier	VII		Thulium-171	IV
			U	Uranium-230	II
				Uranium-232	I
				Uranium-233	II
				Uranium-234	II
Ta	Tantalum-182	III		Uranium-235	III
				Uranium-236	II
Tb	Terbium-160	III		Uranium-238	III
				Uranium natural	III
				Uranium enriched	III
				Uranium depleted	III

Classification of Radionuclides into Transport Groups (continued)

Symbol	Radionuclide	Group
V	Vanadium-48	IV
	Vanadium-49	III
W	Tungsten-181	IV
	Tungsten-185	IV
	Tungsten-187	IV
Xe	Xenon-125	III
	Xenon-131m	III
	Xenon-131m (uncompressed) [a]	V
	Xenon-133	III
	Xenon-133 (uncompressed) [a]	VI
	Xenon-135	II
	Xenon-135 (uncompressed) [a]	V
Y	Yttrium-88	III
	Yttrium-90	IV
	Yttrium-91m	III
	Yttrium-91	III
	Yttrium-92	IV
	Yttrium-93	IV
Yb	Ytterbium-175	IV
Zn	Zinc-65	IV
	Zinc-69m	IV
	Zinc-69	IV
Zr	Zirconium-93	IV
	Zirconium-95	III
	Zirconium-97	IV

[a] Uncompressed shall mean at a pressure not exceeding one atmosphere absolute at 0°C. and mean sea level.

1. Write a procedure for a survey of a container of radioactive waste materials before shipment. Include equipment and specific tests to be made.

2. What are the options available if the radiation field around a container of radioactive waste is found to be 125 millirem per hour at a distance of three feet?

3. Write a procedure for the performance of a smear test.

4. What instrument should be used to determine whether the radiations present in a sample are alpha, beta, or gamma radiations?

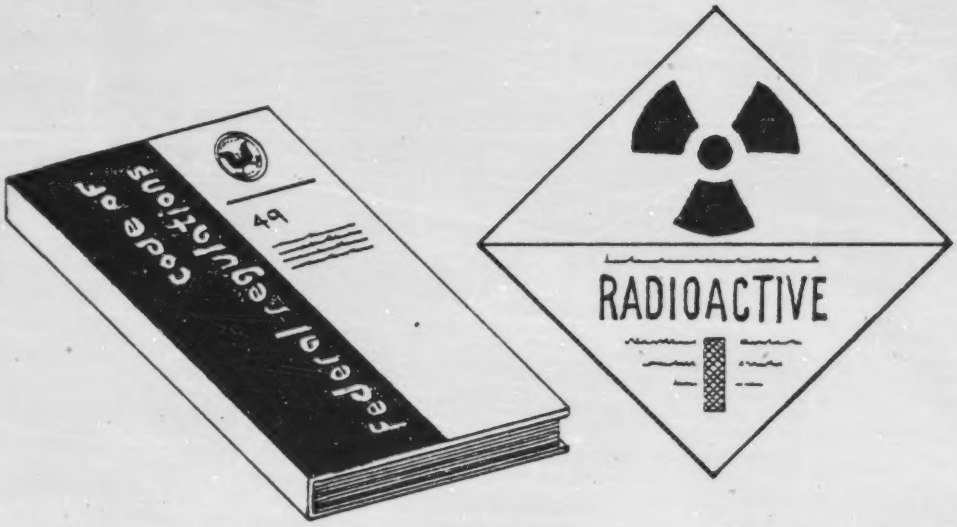
5. Given a choice of an alpha scintillation counter, a Geiger-Mueller counter, or a pulse height analyzer equipped with a photomultiplier tube and a sodium iodide crystal, which instrument would be best suited to count a smear sample known to contain ^{14}C?

6. What actions must be taken if a contamination smear sample indicates an activity level of 1.7 microcuries of cobalt-60 per square centimeter on the external surface of a barrel of radioactive waste material to be shipped?

NUCLEAR TECHNOLOGY

MODULE 21-5

REGULATIONS FOR THE TRANSPORTATION OF
RADIOACTIVE WASTE MATERIALS



RADIOACTIVE MATERIALS DISPOSAL
AND MANAGEMENT

COURSE 21

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

COURSE MODULES

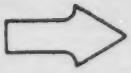
COURSE 21 RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

MODULE 21-1 Radioactive Waste Disposal Procedures

MODULE 21-2 Routine Sampling of Radioactive Waste

MODULE 21-3 Radioactive Waste Disposal Regulations

MODULE 21-4 Measurement of External Radioactive Contamination



MODULE 21-5 Regulations for Transportation of Radioactive Materials

MODULE 21-6 Packaging and Monitoring of Radioactive Materials for Shipment

MODULE 21-7 Leak Tests of Sealed Radioactive Sources

Copyright© 1980

Center for Occupational Research and Development, Incorporated
4800 Lakewood Drive, Waco, Texas 76710

Reproduction or publication of the content in any manner, without the express permission of the Center for Occupational Research and Development, Incorporated, is prohibited. No liability is assumed with respect to the use of the information herein.

INTRODUCTION

The transportation of radioactive waste materials is a complex interaction between government, science, and industry. The development of acceptable, safe limits, containers, and procedures has been a long and difficult task, carried to an international scale, with a continuing effort toward development of new technology and safety standards.

Because many organizations are involved in the promulgation of regulations concerned with the transportation of radioactive wastes, the technician must be introduced to some of these organizations and their influences upon the nuclear industry.

MODULE PREREQUISITES

The student should have completed a course in basic algebra and all previous modules in Course 21, "Radioactive Materials Disposal and Management."

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Define the following terms:
   - Carrier.
   - Certification.

Containers.
DOT.
Fissile Class I.
Fissile Class II.
Fissile Class III.
Fissile classification.
Fissile materials.
ICC.
Warning labels.
OHM.
Warning placard.
Shipping papers.

2. List the federal agencies that regulate the transportation of radioactive wastes.
3. Enumerate the three types of agencies involved in the regulation of the transportation of radioactive waste materials.
4. List and describe the requirements for each of the three types of labels that could be required for containers of radioactive waste materials.
5. Describe the advantages and disadvantages of shipping radioactive waste materials by truck.
6. List and describe the DOT regulations that apply to packaging specifications and shipping papers for radioactive waste materials.
7. Discuss the shipper's responsibilities for shipping radioactive waste materials.
8. List and discuss the placarding requirements for vehicles that contain radioactive waste materials.
9. Discuss the carrier's responsibilities in shipping radioactive waste materials.

Inclusion of all of the regulations of all the states, as well as the federal government, is beyond the scope of this module. Even the brief, concise regulations of the International Atomic Energy Agency (IAEA) is a 135-page document; therefore, this module can be concerned only with an introduction to the federal regulations, with a brief mention of state regulations.

Regulations of the transportation of radioactive waste material provide two valuable functions for the protection and safety of the public: (1) the establishment of safety standards and (2) the control of radiation hazards. Since many agencies are involved, however, the applicable regulations are scattered, and often buried, in regulations concerned with other hazardous materials. This module contains a listing of applicable Federal regulations, but the list should not be construed to be complete. Because these regulations are changing continually, such a list can serve only as a guide.

Radioactive waste material is among the many potentially hazardous cargoes being shipped across the United States. Shipments of radioactive waste can be expected to increase as the nuclear industry continues to grow. In the power industry alone, the need to transport radioactive wastes from one site to another increases as the public demand for energy increases. Because of this we can expect to see more and more radioactive waste materials transported on our nation's rails, water, and highways.

In all major industries, certain words are used with specific meanings. Transportation definitions are as follows:

1. The term "carrier" refers to any person or organization engaged in the transportation of passengers or property, as a common, contract, or private carrier, or a freight forwarder (as those terms are used in the Interstate Commerce Act, as amended, or by the U.S. Postal Service).
2. "Containers" are the receptacles on which primary reliance is placed for the retaining of the radioactive material during transport.
3. "Fissile classification" is the classification of a package or shipment of fissile materials according to the controls needed to provide nuclear criticality safety during transportation as follows:
   a. Fissile Class I consists of packages that may be transported in unlimited numbers and in any arrangement and that require no nuclear criticality safety controls during transportation. For purposes of nuclear criticality safety control, a transport index is not assigned to Fissile Class I packages; however, the external radiation levels may require a transport index number.
   b. Fissile Class II packages may be transported together in any arrangement but in numbers that do not exceed a transport index of 50. For purposes of nuclear criticality safety control, individual packages may have a transport index of not less than 0.1 and not more than 10. The external radiation levels may require a higher transport index number than criticality considerations but not to exceed 10. Such shipments require no nuclear criticality safety control by the shipper during transportation.

c. Fissile Class III consists of shipments of packages that do not meet the requirements of Fissile Class I or II and that are controlled in transportation by special arrangements between the shipper and the carrier to provide nuclear criticality safety.

4. Fissile materials are uranium-233, uranium-235, plutonium-238, plutonium-239, and plutonium-241.

AGENCIES INVOLVED IN REGULATION

Agencies involved in the regulation of radioactive waste materials transportation are divided into three categories:

- Those concerned with the carriers.
- Those concerned with safety regulations.
- Those that regulate commodities.

Although there is some overlap in regulations among agencies, each group strives to ensure that there is as little regulatory duplication and conflict among the agencies as possible.

CARRIER REGULATORY AGENCIES

Carrier regulatory agencies are concerned primarily with the economics of transportation. These agencies control a carrier's authority to operate and regulate the fees that the carriers are allowed to charge.

The federal agency that regulates surface transportation is the Interstate Commerce Commission (ICC). All of the surface carriers that are operating in interstate commerce derive their authority for operation from the ICC.

State carrier regulatory agencies usually are titled as some type of Public Service Commission or Agency and are organized almost like the ICC in structure, function, and role.

AGENCIES THAT REGULATE SAFETY

Protection of the property and lives of shippers, their employees, and the general public from the hazards of radioactive waste transportation is the concern of the safety regulatory agencies.

The safety regulatory agency of the federal government in transportation matters is the Department of Transportation (DOT). The DOT administers safety regulations through its various agencies. Surface transportation safety regulations on land are administered through the Federal Highway Administration (FHA) and the Federal Railroad Administration (FRA); and safety on the inland and intercoastal waterways is administered through the U.S. Coast Guard. The use of any radioactive material or other sources of radiation by a licensee of the NRC is subject to NRC regulations (NRC Rules and Regulations: Title 10, Code of Federal Regulations, Parts 20 and 71).

State-level safety regulatory agencies are identified by a multitude of titles; however, since most radioactive waste material is transported by truck, the most prominent agency is the Department of Transportation.

AGENCIES THAT REGULATE COMMODITIES

Commodity regulatory agencies are concerned with the protection of life and property from the dangers involved with specific materials. In addition to radioactive materials, commodity regulators are concerned with explosives, corrosives, and flammable materials.

The federal governmental agencies responsible for commodities that apply to radioactive waste materials include the Department of Transportation (DOT), the Nuclear Regulatory Commission (NRC), and the Department of Energy (DOE). The NRC/DOE regulations originally were formulated by their predecessor organization, the Atomic Energy Commission (AEC). Likewise, the DOT regulations are based upon the AEC regulations that were in effect prior to the formation of the DOT. Duplication of regulatory efforts was avoided when the AEC and the DOT adopted an agreement whereby each would operate in the areas of its particular competence and would review the regulations of the other before producing new regulations. This policy was carried forward by the NRC and the DOE when the AEC was split. The DOT is charged with the responsibility for safety surveillance during the transportation of radioactive waste material by all methods of transport. The Office of Hazardous Materials (OHM) within the DOT is charged with coordination and technical expertise in all matters that relate to the transportation of radioactive waste materials.

DOT regulations are generalized and include provisions for the carriers of hazardous materials who deal with the loading, unloading, tiedown, and bracing of containers; the routing and handling of containers in transit; the qualifications of, and instruction for, personnel; the condition

of mechanical equipment and the other factors that affect the safety of people and property in the transportation of radioactive waste material.

Commodity regulatory agencies also exist at the state level; usually, these agencies are State Health Departments. Within the State Health Department, the Occupational, Environmental, and/or Radiological Health Division probably will have the responsibility for implementation and enforcement of state regulations.

APPLICABLE FEDERAL REGULATIONS

Two Public Laws affect the regulations of the various agencies. The first of these is Public Law 86-710, which became effective on 6 September 1960. This law revised sections 832 and 833 of Title 18, chapter 39 of the United States Code as follows:

- Unless specifically approved under emergency conditions, any person who knowingly transports, carries or conveys within the United States any dangerous explosives, radioactive materials, or etiological (illness-causing) agents, except for small quantities transported under conditions established by the Department of Transportation, on or in any passenger vehicle operated by any carrier engaged in interstate or foreign commerce by land shall be fined or imprisoned as provided in the act.
- Shipments of radioactive materials made by or under the direct supervision of the Atomic Energy Commission (now the DOE) and the Department of Defense for the purpose of national security which are escorted

by personnel specifically designated by the cognizant Department are exempt from the requirements of Sections 832 and 833.

- Unescorted shipments of radioactive materials made by or under the direction of the Atomic Energy Commission (now the DOE) or the Department of Defense are not subject to inspection by the carrier if each package and the bill of lading are plainly marked "radioactive materials."
- Any person who delivers to any carrier engaged in the transportation of passengers or property by land or water, any explosive or other dangerous article, under false or deceptive marking, invoice, or shipping order or without plainly marking on the outside of each package the contents thereof shall be fined or imprisoned as provided in the act.

The second law is the Department of Transportation Act, Public Law 89-670, 80 Stat. 931, and was approved and became effective on 15 October 1966. This law established the Department of Transportation and vested all of the functions, powers, and duties related to the field of transportation in the Secretary of Transportation.

Additionally, the following publications contain the regulations promulgated by the aforementioned agencies, affecting the transportation of radioactive waste materials.

- Title 49, Code of Federal Regulations, Parts 170 to 199. These rules of the DOT apply to the classification, packaging, marking, labeling, and shipment of radioactive waste materials by all surface means.
- Title 46, Code of Federal Regulations, Parts 146 and 149. Rules of the U.S. Coast Guard apply to shipments

via water transportation. These regulations are essentially the same as those of Title 49 but contain some specific requirements that are peculiar to the shipment of radioactive materials by water.

- Title 10, Code of Federal Regulations, Part 71. Rules by the NRC apply to the shipment of certain fissile materials and large quantities of other NRC licensed materials.

Changes in these regulations are published daily in the Federal Register.

FEDERAL REGULATIONS

Each state has regulations that apply to environmental hazards, radioactive materials, and radiation protection. The majority of the states have patterned their regulations concerning the transportation of radioactive waste materials after the federal regulations.

ADDITIONAL SOURCES OF REGULATIONS AND TARIFFS

Additional agencies that publish regulations or tariffs that affect the transportation of radioactive waste materials include the following:

- The American Trucking Associations (ATA), Inc., "Dangerous Articles Tariff No. 15, Department of Transportation Regulations for Governing Transportation of Hazardous Materials by Motor, Rail, and Water, Including Specifications for Shipping Containers, November 15, 1972."

- The Bureau of Explosives, Association of American Railroads, "R. M. Grazianc's Tariff No. 25, Hazardous Materials Regulations of the Department of Transportation, Including Specifications for Shipping Containers, March 24, 1972."
- The International Atomic Energy Agency, Regulations for the Safe Transport of Radioactive Materials, Safety Series #6, 1973 Edition.

These regulations, and others, can affect the transportation of radioactive waste materials.

CLASSIFICATION AND PACKAGING

The classification and packaging of radioactive waste material is quite involved. Some of the aspects of classification were mentioned in Module 21-4, "Measurement of External Radioactive Contamination." These aspects will be expanded in Module 21-6, "Packaging and Monitoring of Radioactive Materials for Shipment," in which the packaging requirements will be considered at length. Basically, the packaging requirements for radioactive waste materials are the same as if the waste were any new radioactive material to be shipped. The criteria for radiation, containment, packaging, and shipping do not change simply because the material is classified as waste.

METHODS OF TRANSPORTATION

The transportation of radioactive waste materials begins at the site of the loading of the containers of radioactive wastes. The containers then are moved by truck, rail, barge, ship, or combination thereof, to a site for further processing, storage, or burial. The major radioactive material being shipped at this time consists of irradiated fuel elements. These elements always are shipped in specially-designed containers. Figures 21-5-1 through 21-5-3 are illustrations of the shipping of irradiated fuel elements by truck, rail, and barge, respectively. In the majority of cases, the shipment of radioactive waste material is by truck.

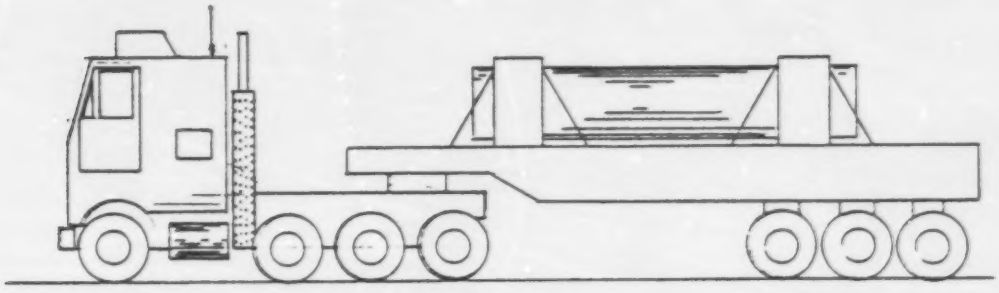


Figure 21-5-1. A typical truck-shipping arrangement for irradiated fuel elements.

Transportation of radioactive wastes by truck requires a specialized carrier, experienced in heavy hauling, knowledgeable in the specific regulations and requirements for the transportation of radioactive waste materials, and having drivers trained in the fundamentals of health physics.

Usually, transportation by truck is in "sole-use" vehicles, in which case arrangements can be made to route the shipment specially in order that heavily-populated areas, toll roads, tunnels, and bridges that prohibit such shipments can be avoided. The shipment should be under the constant surveillance of the driving team. There should be radiation survey instruments aboard the truck, and the drivers should have both verbal and written instructions that indicate the proper course of action in the event that abnormal conditions are detected or a traffic accident occurs.

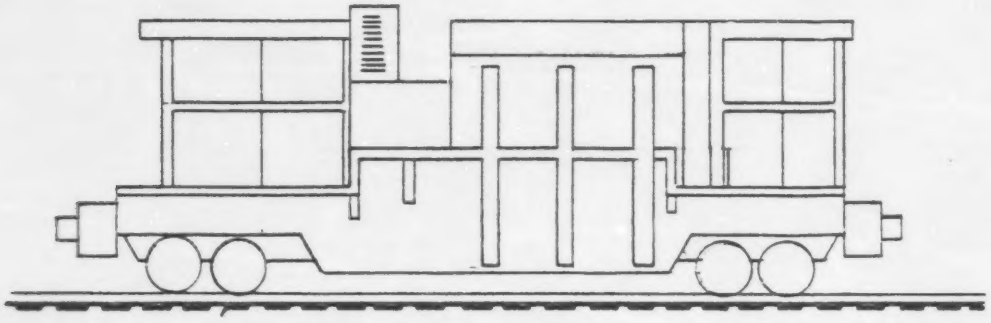


Figure 21-5-2. A typical rail-car shipping arrangement.

Rail shipments usually have exclusive vehicle use, and radioactive waste materials are not shipped with other dangerous materials. The general practice of the rail industry is to "block" a train in such a manner that radioactive waste materials are placed as far as possible away from explosive, flammable, or other dangerous materials.

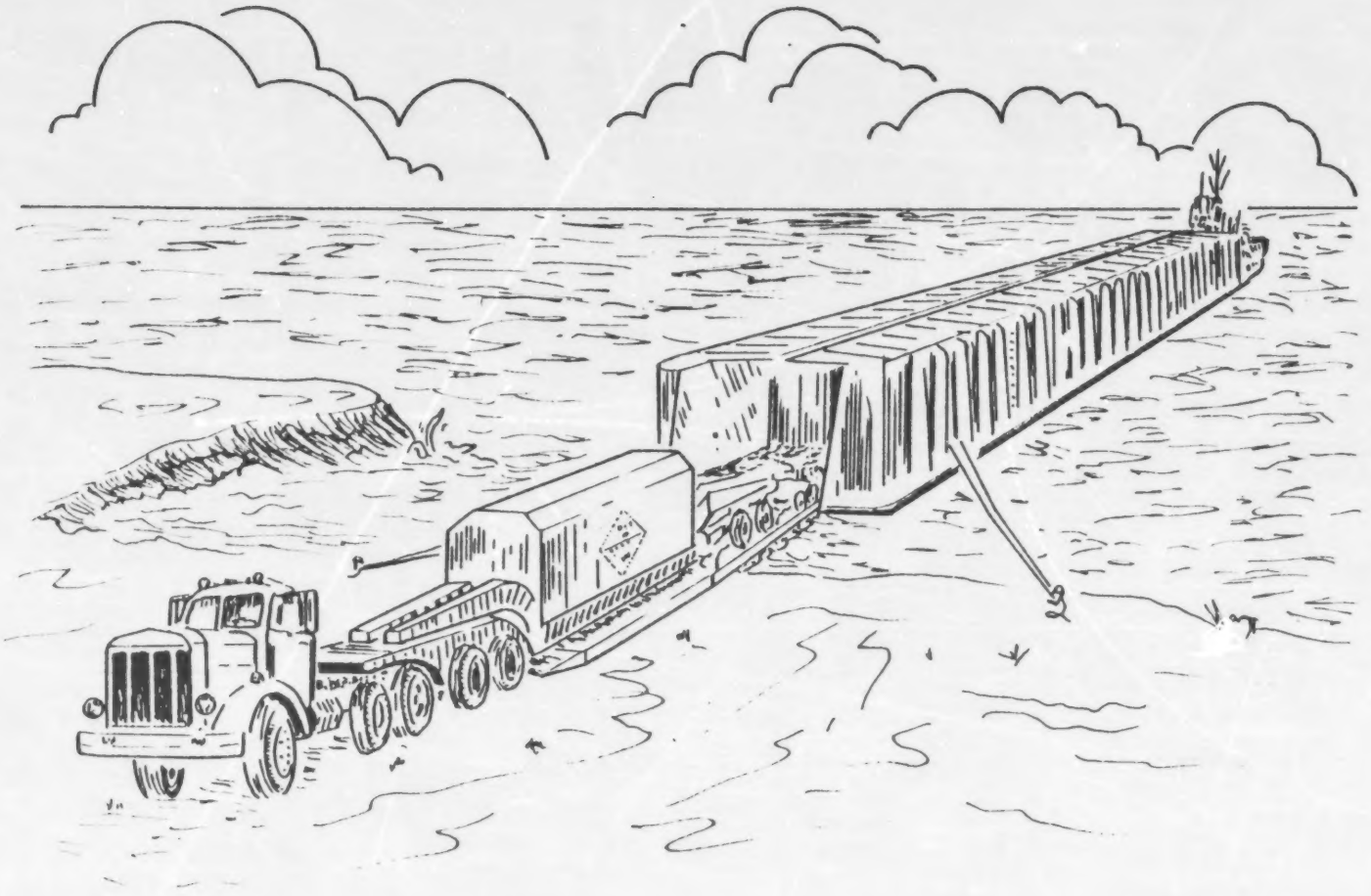


Figure 21-5-3. Loading and unloading of an integrated barge.

HIGHWAY SHIPMENTS

All vehicles that transport freight must comply with the regulations of the states within which they operate. These regulations include such things as vehicle height and width, highway weight, length and combination of vehicles, speed and operation time, and regulations concerning special permits when the vehicle is not in compliance with a regulation. Regulations are not uniform from state to state; therefore, a shipment that has traveled in one state may require special permits before being allowed to cross into another state.

Even when special permits have been issued, some states require that radioactive waste materials be transported only during daylight hours and on weekdays. Other requirements may include such items as special equipment, escort, highway commission approval, health department approval, route analysis and approval, and a specified route.

Regardless of the multitude of restrictions, truck shipment is, by far, the fastest and most expedient method for the transporting of radioactive waste materials.

SHIPMENT BY RAIL

The major advantage of rail shipment of radioactive waste materials is that a much greater quantity of material than possible in truck shipment can be included in a single load, thereby providing fewer opportunities for accident.

There are, however, several offsetting disadvantages. First and foremost is that rail service is not provided at

all sites. The problems of transportation to the nearest railhead and transfer from truck to rail car may be almost insurmountable. Secondly, some rail carriers refuse to carry shipments of radioactive wastes under their classification as a common carrier. This problem eventually may disappear, since the number of refusals appear to be decreasing.

Many areas have only partial rail service and no weekend service. Likewise, railroad schedules are unreliable. This, coupled with delays in loading and delays in transit, can increase greatly the cost of radioactive materials shipment.

The location of the site, the number of connecting rail lines, and the ability of the railroads to decrease transportation time are the major factors that affect any decision concerning rail shipment as a means of transporting radioactive waste materials.

SHIPMENT BY WATER

The advantage of shipment of radioactive waste materials by water is the greater mass that can be accommodated. Quantity limitations that are restrictive for both truck and rail shipment are practically nonexistent for barge shipment.

There are, regrettably, severe disadvantages. There may be few docking facilities in areas at which they are needed. There may be no direct water routes between sites. Transportation by water is slow, which increases the cost and the opportunity for accidents.

INTERMODAL SHIPMENTS

The difficulties encountered in the long-distance truck shipment of radioactive waste materials may be such that a more desirable arrangement is the combination of trucking with either rail or barge shipment. Such combination shipments could be made with specially-designed trucks, rail cars, or barges, or with existing equipment.

LABELS FOR CONTAINERS OF RADIOACTIVE MATERIALS

49CFR173.414 requires that the labels for packages of radioactive materials must be diamond shaped, with sides at least 4 inches in length and with specific coloration based upon the amount of radiation emitted from the container. The printing on the label must be black, inside a black-line border measuring at least 3-1/2 inches on each side. NOTE: The colorations differ from those of the standard radioactive warning and hazard signs.

RADIOACTIVE WHITE-I LABEL

This label must be white. (Refer to Figure 21-5-4). The single vertical bar located in the lower half of the label must be bright red. Labels of this type must be placed on two opposing sides of each package of radioactive materials that exhibit a surface dose rate that does not exceed 0.5 millirem per hour at any point on the external surface of the package. This type of label is not authorized for Fissile Class II packages.

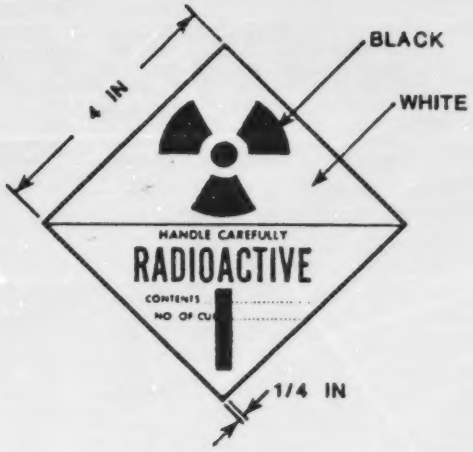


Figure 21-5-4. Radioactive White-I label.

RADIOACTIVE YELLOW-II LABEL

The upper half of this label must be bright yellow in color and the bottom half must be white. (Refer to Figure 21-5-5.) There must be two bright red vertical bars on the lower half of the label. Labels of this type must be placed on two opposing sides of two following types of packages:

- Packages that have an external surface dose rate that does not exceed 10 millirem per hour at any point on the surface of the package and does not exceed 0.5 millirem per hour at any point 3 feet from the external surface of the package.
- Packages for which the transport index does not exceed 0.5 at any time during transportation.

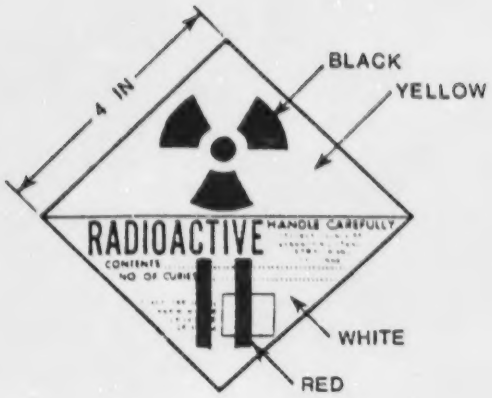


Figure 21-5-5. Radioactive Yellow-II label.

RADIOACTIVE YELLOW-III LABEL

The upper half of this label must be bright yellow and the bottom half white (Figure 21-5-6). There must be three bright red vertical bars located in the lower half of the label. According to 49CFR173.399, labels of this type must be applied to two opposite sides of four different types of packages. The four package types are as follows:

- Each package that has a surface dose rate in excess of 10 millirems per hour.
- Each Fissile Class III package.
- Each package that contains a large quantity of radioactive materials as defined in 49CFR173.389(b).
- Each package transported under a special permit issued in response to a petition outlined in 49CFR170.13(b).

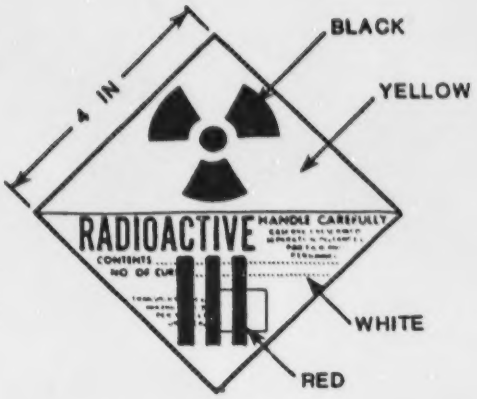


Figure 21-5-6. Radioactive Yellow-III label.

EMPTY CONTAINER LABEL

49CFR173.29(e), 173.402(a)(13), and 173.413(a) require that empty radioactive material containers must be labeled as such with a square label that measures at least 6 inches on each side (Figure 21-5-7). The label must be white and printed in black letters not less than one inch in height. In order to be labeled empty, a container must be free of significant removable contamination and have a surface dose rate that does not exceed 0.5 millirem per hour. When a container meets these criteria, the EMPTY label must be applied to cover old labels that have not been removed, destroyed, or obliterated.

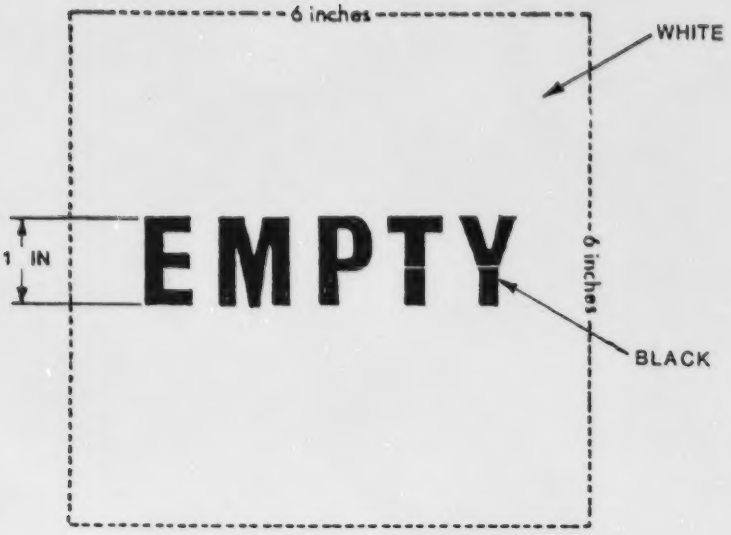


Figure 21-5-7. Empty container label.

RESPONSIBILITIES OF THE SHIPPER

The shipper of radioactive waste materials must ensure that the containers meet specifications and that appropriate papers are prepared to certify that the materials and packaging is in compliance with DOT regulations.

PACKAGING SPECIFICATIONS

49CFR173.24(C)(1) requires that when a shipper of radioactive waste materials provides shipping containers, said shipper is responsible for ensuring that the containers meet DOT or ICC specification. All the parts and fittings of these containers must be assembled in their proper place.

The containers must be marked with their DOT or ICC specification numbers and gross-weight.

SHIPPING PAPERS

A shipper of radioactive materials is required by 49CFR173.427(a)(5) to provide shipping papers that include these items:

- The Transport Group or Groups of the radioactive material if in normal form.
- The name of the radionuclides and a description of their physical and chemical form if the material is in normal form.
- The activity, in curies, of the radioactive material.
- The type of label applied to the package; that is, Radioactive White-I, Radioactive Yellow-II, or Radioactive Yellow-III.
- For fissile radioactive materials, the fissile class of the package, and the weight, in kilograms, of the fissile isotope.

CERTIFICATION

The shipper of radioactive waste materials, like the shipper of any dangerous material by highway or rail, must attach a certification to the shipper papers in order to meet the requirements of 14CFR102.2; 49CFR173.430, 174.511, 175.654, 176.704(a), and 177.819. The certification must be signed by the shipper and must state:

"This is to certify that the above named articles are properly classified, described, packaged, marked, and labeled, and are in proper condition for transportation, according to the applicable regulations of the Department of Transportation."

THE PLACARDING OF VEHICLES THAT TRANSPORT RADIOACTIVE MATERIALS

Title 49 of the Code of Federal Regulations requires that highway vehicles and rail vehicles that transport radioactive materials must be placarded to mark them as such. The placards for each vehicle type are different.

Highway Vehicles

Vehicles for the transport of packages of radioactive materials bearing a Radioactive Yellow-III label must be placarded by the carrier, or the shipper must placard sole-use vehicles that contain full loads of low-specific-activity materials. The placards must be printed in black letters on yellow backgrounds. Figure 21-5-8 is an example of a highway placard. The letters must be 4 inches in height with a stroke width of 5/8 inch. The vehicle is required to be placarded on the front, on the rear, and on each side (49CFR177.832(a)(4)).

Figure 21-5-8. Highway placard.

Rail Vehicles

The sections of 49CFR that apply to the placarding of rail vehicles used to transport radioactive materials include 174.655(e) and 176.705. (Refer to Figure 21-5-9.)

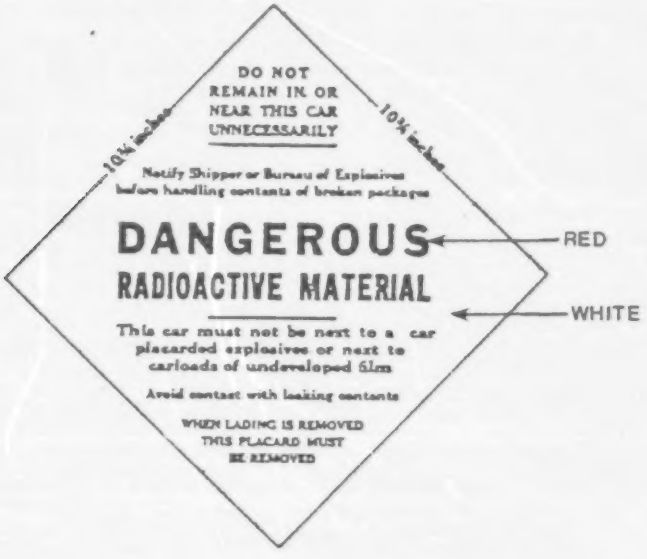


Figure 21-5-9. Rail vehicle placard.

These regulations require both that unattended baggage cars or express cars that contain packages marked with Radioactive Yellow-III label and that carload lots of low-specific-activity materials for rail transport must be placarded by the carrier. The placard must be diamond shaped, measuring 10-3/4 inches on each side. The printing must include the phrase "Dangerous Radioactive Material" printed in red on a white background.

RESPONSIBILITIES OF THE CARRIER

The carrier is responsible for the acceptance of the shipment and shipping papers and for accidents or delays in shipment.

Shipping Papers

Regulations 49CFR174.510(a), 175.652(a), 176.604, 176.704(a), and 177.817 specify that a carrier must not accept packages of radioactive materials for shipment unless the shipper papers include one of the following:

- The proper description and classification of the material.
- Or the shippers certification with respect to classification and packaging of the material.

Accident or Delay

Carriers that transport radioactive materials must perform two actions in case of accident, fire, breakage, unusual delay, or if a shipment goes astray. The regulations cited are 49CFR174.588, 174.679, and 177.861. In the event of one or more of these occurrences, the carrier must perform the following two tasks:

- Immediately notify the shipper and the Department of Transportation.
- Restrict the occupancy of cars, buildings, areas, or equipment in which the radioactive materials have been spilled until the radiation dose rate at any accessible surface is less than 0.5 millirem per hour and until there is no significant removable surface contamination.

Appendix A of this module contains a copy of a communication published by the NRC to all the radioactive material licensees across the nation. This publication by the NRC illustrates how the government agency responds nationally to a request from State governors regarding radioactive waste disposal.

EXERCISES

1. Prepare a sequential list of the NRC regulations that apply to the transportation of radioactive waste materials.

2. Prepare a sequential list of the DOT regulations that apply to the transportation of radioactive waste materials.
3. List a federal regulatory agency that is involved in the regulation of radioactive waste materials transportation for each of the following criteria:
   Carrier Regulatory Agency.
   Safety Regulatory Agency.
   Commodity Regulatory Agency.
4. List the appropriate label required for packages of radioactive materials that have surface activities of –
   0.07 mrem/h.
   0.6 mrem/h.
   11 mrem/h.
5. Describe the placarding requirement for a truck that transports radioactive waste materials. (Include a sketch.)
6. Describe the placarding requirement for an unattended baggage car that transports radioactive materials. (Include a sketch.)
7. List the responsibilities of a shipper of radioactive waste materials.
8. List the responsibilities of the carrier of radioactive waste materials.

MATERIALS

1 copy of Title 49, Code of Federal Regulations, Parts 170-179.

1 copy of Title 10, Code of Federal Regulations, Parts 19 to 71.

PROCEDURES

1. Locate and outline the sections of 49CFR and 10CFR concerned with the labeling of containers of radioactive materials for transportation.
2. Locate sections of 10CFR and 49CFR that apply to accidents that occur during the transportation of radioactive materials, and prepare a procedure to be followed when such an accident occurs.

None.

IAEA. Regulations for the Safe Transport of Radioactive Materials. Revised Edition. New York: Unipub, Inc., 1973.

Rules and Regulations: Title 10, Code of Federal Regulations. Washington, D.C.: United States Nuclear Regulatory Commission, 1978 (with Supplements through 11-28-79).

Southern Interstate Nuclear Board. Transportation of Nuclear Spent Fuel. Atlanta, GA: SINB.

Texas Regulations for Control of Radiation. Austin, TX: Texas Department of Health, Division of Occupational Health and Radiation Control.

APPENDIX A

IE Bulletin No. 79-20

PACKAGING, TRANSPORT AND BURIAL OF LOW-LEVEL RADIOACTIVE WASTE

Accession No: 7908070524
SSINS No: 6820

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, D.C. 20555

August 10, 1979

IE Bulletin No. 79-20

PACKAGING, TRANSPORT AND BURIAL OF LOW-LEVEL RADIOACTIVE WASTE

Description of Circumstances:

Low-level radioactive waste is that waste which can be transferred and shipped to one of three waste burial facilities which are located in and licensed by the Agreement States of Nevada, South Carolina, and Washington. On July 10, 1979, the Governors of the three states notified NRC Chairman Hendrie of the serious and repeated disregard for rules governing the shipments of low-level radioactive wastes to these burial facilities.

Examples of violations of Agreement State, DOT and NRC rules follow:

Improperly packaged uranium fines igniting packaged liquid scintillation vials in combustible waste is believed to have caused a fire and destruction of a truck at the Beatty, Nevada burial facility on May 14, 1979.

On July 2, 1979, three of twelve steel containers shipped to the Beatty burial facility were found to be leaking radioactive material. The material was described on the bill of lading as being a solid inorganic salt (evaporator concentrates solidified with urea formaldehyde) from a reactor facility. The Governor of the State of Nevada ordered the drums to be shipped out of the state and the burial facility was temporarily closed.

On July 30, the first shipment into the reopened Beatty facility contained free liquid in "solid" material. The radioactive contents were sand filters used at an insitu leaching process at a uranium mill.

Forty-three shipments with sixty-three deficiencies were observed during the package inspection program between April 10 and July 5, 1979, by the Agreement State of South Carolina, at the Barnwell, S.C. burial facility. The shipments were from reactor, medical, industrial and military facilities.

On June 28, 1979, the Federal Highway Administration issued a Notice of Violation to a reactor facility proposing a $10,000 fine for truck contamination resulting from improper closures on 55-gallon drums on LSA material and for improper loading of the drums on the vehicle.

These are a few examples of shipments of radioactive material to burial facilities which did not fully meet NRC, DOT and Agreement State requirements which were developed to protect the health and safety of the public. The Governors of the three States with licensed burial facilities have indicated that if the situation is not rectified, they may have to initiate actions which would deny use of the three burial sites by violators.

Sources of Information:

The DOT regulatory requirements can be found in 49 CFR Parts 170-179. The NRC regulatory requirements can be found in 10 CFR Parts 19 to 71. The NRC regulatory requirements for Agreement State licensees in non-agreement states are in 10 CFR Part 150. Copies of the regulations may be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402.

Information about licensing requirements for NRC packages can be obtained from the NRC Transportation Branch (301-427-4122). Information about DOT packaging and transport requirements can be obtained by calling the DOT office of Hazardous Materials (202-426-2311).

Action To Be Taken By Licensees:

To assure the safe transfer, packaging, and transport of low-level radioactive waste, each licensee is expected to:

1. Maintain a current set of DOT and NRC regulations concerning the transfer, packaging and transport of low-level radioactive waste material.

2. Maintain a current set of requirements (license) placed on the waste burial firm by the Agreement State of Nevada, South Carolina, or Washington before packaging low-level radioactive waste material for transfer and shipment to the Agreement State licensee. If a waste collection contractor is used, obtain the appropriate requirements from the contractor.

3. Designate, in writing, people in your organization who are responsible for the safe transfer, packaging and transport of low-level radioactive material.

4. Provide management-approved, detailed instructions and operating procedures to all personnel involved in the transfer, packaging and transport of low-level radioactive material. Special attention should be given to controls on the chemical and physical form of the low-level radioactive material and on the containment integrity of the packaging.

5. Provide training and periodic retraining in the DOT and NRC regulatory requirements, the waste burial license requirements, and in your instructions and operating procedures for all personnel involved in the transfer, packaging and transport of radioactive material. Maintain a record of training dates, attendees, and subject material for future inspections by NRC personnel.

6. Provide training and periodic retraining to those employees who operate the processes which generate waste to assure that the volume of low-level radioactive waste is minimized and that such waste is processed into acceptable chemical and physical form for transfer and shipment to a low-level radioactive waste burial facility.

7. Establish and implement a management-controlled audit function of all transfer, packaging and transport activities to provide assurance that personnel, instructions and procedures, and process and transport equipment are functioning to ensure safety and compliance with regulatory requirements.

8. Perform, within 60 days of the date of this bulletin, a management-controlled audit of your activities associated with the transfer, packaging and transport of low-level radioactive waste. Maintain a record of all audits for future inspections by NRC or DOT inspectors. (Note: If you have an established audit function and have performed such an audit of all activities in Items 1-6 within tne past six months, this audit requirement is satisfied.)

No written reply to this Bulletin is required. NRC inspectors will examine your continuing response during future inspection of your activities. Licensees who do not generate low-level waste for burial do not need to take actions described above. If you desire additional information regarding this matter, contact the Director of the appropriate NRC Regional Office.

1. List the federal regulations that apply to the transportation of radioactive waste material.

2. Describe three types of agencies involved in the regulation of the transportation of radioactive waste materials.

3. List and describe the requirements that would cause a Radioactive Yellow-III label to be affixed to a shipment of radioactive waste materials.

4. Describe the advantages and disadvantages of shipping radioactive waste materials by truck.

5. List and describe the DOT regulations that apply to packaging specifications for radioactive material.

6. Discuss the shippers responsibilities for shipping radioactive waste materials.

7. Describe the placarding requirements for an unattended rail car used to transport radioactive waste materials.

8. Discuss the responsibilities of a carrier of radioactive waste material in case of an accident.

NUCLEAR TECHNOLOGY

MODULE 21-6

PACKAGING AND MONITORING OF RADIOACTIVE MATERIALS FOR SHIPMENT

RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

COURSE 21

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

COURSE 21 RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

MODULE 21-1 Radioactive Waste Disposal Procedures

MODULE 21-2 Routine Sampling of Radioactive Waste

MODULE 21-3 Radioactive Waste Disposal Regulations

MODULE 21-4 Measurement of External Radioactive Contamination

MODULE 21-5 Regulations for Transportation of Radioactive Materials

MODULE 21-6 Packaging and Monitoring of Radioactive Materials for Shipment

MODULE 21-7 Leak Tests of Sealed Radioactive Sources

Copyright© 1980

Center for Occupational Research and Development, Incorporated
4800 Lakewood Drive, Waco, Texas 76710

Reproduction or publication of the content in any manner, without the express permission of the Center for Occupational Research and Development, Incorporated, is prohibited. No liability is assumed with respect to the use of the information herein.

INTRODUCTION

The packaging and shipment of radioactive material is a complicated process. Every step is regulated, and instructions must be carried out exactly. The reference most often used is "Title 49, The Code of Federal Regulations, Parts 100 to 199." This volume contains more than 1200 closely-printed pages. It is an exhaustive listing of regulations and, unless a few shortcuts are taken, it is exhausting to use. The user must struggle through a tortuous maze of definitions, procedures, prohibitions, and rules, often emerging more confused than ever.

As with any trek through a wilderness, it is best to have a guide – someone who has been there before and has come back alive. This module is intended to be that guide. Once the right path is shown, it will be surprisingly easy to find again.

The first step is to scout ahead and establish some bearings – some landmarks to guide the journey about to begin. These "landmarks" are the definitions and explanations in these next pages. Once known, the explorer is equipped with a kind of map, and the wilderness is not the fearsome place it once was.

NOTE: The student must have a copy of 49CFR, Parts 100 to 199 in order to complete this module.

MODULE PREREQUISITES

The student should have completed Modules 21-1, 21-4, and 21-5 of this Course.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Define the following terms:
   - Tariff.
   - Normal-Form Material.
   - Special-Form Material.
   - Transport group.
   - Fissile class.
   - Type "A" quantity.
   - Type "B" quantity.
   - Type "A" packaging.
   - Type "B" packaging.
   - Large-Quantity Material.
   - Small- or Limited-Quantity Material.
   - Low-Specific-Activity Material.
   - Transport Index.
   - Sole use.
   - Fissile classes I, II and III.
   - Stowage control.
   - Yellow-labeled package.
   - White-labeled package.
   - Shippers certification.
   - Placard.
   - Security seal.
2. Given the Transport Index of a radioactive material and a copy of Title 49CFR Parts 100 to 199, locate appropriate stowage control data for the radioactive material.

3. Given a copy of 49CFR, Parts 100 to 199 and the name, the quantity in curies, and the form of a fissile or nonfissile radioactive material, determine the following:

   Transport group of the material.
   Proper shipping name of the material.
   Hazard class of the material.
   Labels required on packages of the material.
   Paragraph references for packaging exceptions and special requirements.
   Whether material is fissile or nonfissile.
   Whether material is Type "A," Type "B," Small-Quantity, Large-Quantity, or a Low-Specific-Activity Material.

4. Given a copy of 49CFR, Parts 100 to 199, list at least three entries that must be made in the shipping papers that accompany radioactive material.

5. List the steps that must be taken when an accident causes suspected radioactive contamination while radioactive material is being transported.

REGULATORY AUTHORITIES

On January 3, 1975, the 93rd Congress passed the Transportation Safety Act of 1974 (Figure 21-6-1). This Act empowered the Secretary of Transportation to issue regulations for the safe transportation of hazardous materials. Persons who transport these materials must be registered with the federal government. The act authorized agents of the Department of Transportation (DOT) to inspect and examine the records and properties of these persons, and also provided for civil penalties to be imposed upon anybody who violates a regulation issued by the Department.

Public Law 93-633
93rd Congress, H. R. 15223
January 3, 1975

An Act

To regulate commerce by improving the protections afforded the public against risks connected with the transportation of hazardous materials, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Transportation Safety Act of 1974".

Figure 21-6-1. The Transportation Safety Act of 1974.

The DOT has regulatory responsibility for the transportation of radioactive materials (RAM). It shares this responsibility with the U. S. Postal Service and the Nuclear Regulatory Commission (NRC). The Postal Service regulates postal shipments of RAM. The NRC issues regulations for safety in the possession and use of source, by-product, and special nuclear materials. The NRC also has established requirements that must be met before a licensee can deliver RAM to the carrier for transport.

Several states have entered into agreements with the NRC whereby the NRC transfers to them regulatory authority over certain types of nuclear material. These "agreement states" have adopted regulations that control the shipment of materials from one agreement state to another. These states also control intrastate shipments. State regulations are modeled, for the most part, after federal regulations.

FEDERAL REGULATIONS

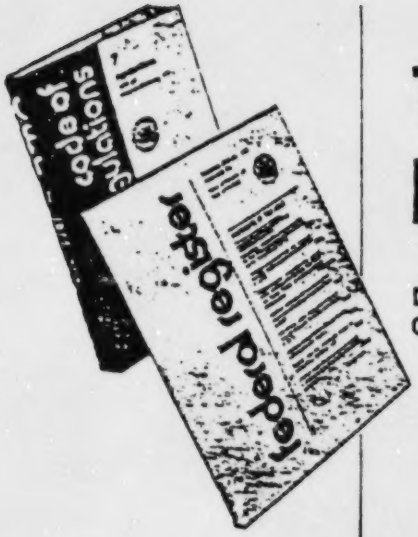
Table 21-6-1 lists the sources of federal regulations that control the transport of RAM. Title 49, Code of Federal Regulations, Parts 100 to 199 (49CFR, 100-199) is the most comprehensive. It is a codification of all the general and permanent rules of the DOT that govern the commercial transportation of hazardous materials. Changes and proposed changes to it are published daily in the Federal Register (Figure 21-6-2).

Title 10, U. S. NRC, and Title 39, U. S. Postal Service, also apply, under certain conditions, to the delivery and shipment of RAM.

TABLE 21-6-1

SOURCES OF FEDERAL REGULATIONS

Title 49	Department of Transportation's Hazardous Materials Regulations, Parts 100-199
	Main Headings
	49CFR170 – Rule-making Procedures of the Materials Transportation Bureau
	49CFR171 – General Information, Regulations and Definitions
	49CFR172 – Hazardous Materials Table and Hazardous Materials Communications Regulations
	49CFR173 – Shippers-General Requirements for Shipments and Packagings
	49CFR174 – Carriage by Rail
	49CFR175 – Carriage by Aircraft
	49CFR176 – Carriage by Vessel
	49CFR177 – Carriage by Public Highway
	49CFR178 – Shipping Container Specifications
	49CFR179 – Specifications for Tank Cars
Title 10	U. S. Nuclear Regulatory Commission
	10CFR71 – Packaging of Radioactive Materials for Transport and Transportation of Radioactive Material Under Certain Conditions
Title 39	Postal Service, U. S. Postal Service Regulations, Part 123. (Postal Regulations for Transport of Radioactive Matter are published in U. S. Postal Service Publication #6, December, 1975, and in the U. S. Postal Manual.)



The Federal Register

DAILY SUPPLEMENT TO THE
CODE OF FEDERAL REGULATIONS . . .

publishes daily the full text of

- ☐ Presidential proclamations
- ☐ Executive orders
- ☐ Reorganization plans
- ☐ Federal regulations that affect every American

Figure 21-6-2. The Federal Register.

TARIFFS

Another source of regulations is a tariff. A tariff is not an official regulation, but a publication of some agency or association that reprints federal regulations and explains how the organization applies and accepts them. They are binding only on the organization's members; for example, the American Trucking Association, Inc., publishes a tariff. This publication is intended to provide a guide to the federal regulations for their members and to set out procedures that their members must follow to meet the regulations.

INTERNATIONAL REGULATIONS

International organizations, such as the International Atomic Energy Agency (IAEA) and the International Air Transport Association (IATA), issue their own regulations. These regulations are not identical with federal regulations, although DOT regulations have been revised to conform substantially to IAEA rules.

CLASSIFICATION OF RADIOACTIVE MATERIALS (RAM)

For packaging and shipping purposes, RAM can be classified according to its form, quantity, and type. There are two forms of RAM: Special-Form Materials and Normal-Form Materials.

Special-Form Materials are those which, if released from a package, might present some direct radiation hazard, but would present little hazard from radiotoxicity and little possibility of contamination (Figure 21-6-3).

Special-Form Materials will not spill or scatter easily. They may be encapsulated as a sealed source or in some massive solid form. Special-Form criteria are specified in 49CFR §173.398 (the symbol § means paragraph). Material must meet or exceed these criteria before it can be categorized as Special Form. It must be able, for instance, to withstand a drop from a distance of 30 feet; heating in air to a temperature of 1475°F; immersion for 24 hours in water at room temperature; and several other tests before it can receive the Special-Form classification. Once classified as Special-Form Material, larger amounts of material can be placed in packages than otherwise would be permitted; and

more material can be shipped in one package. The classification of material as Special-Form Material is left to the shipper or package designer, who, of course, must be certain that this material meets federal specifications.

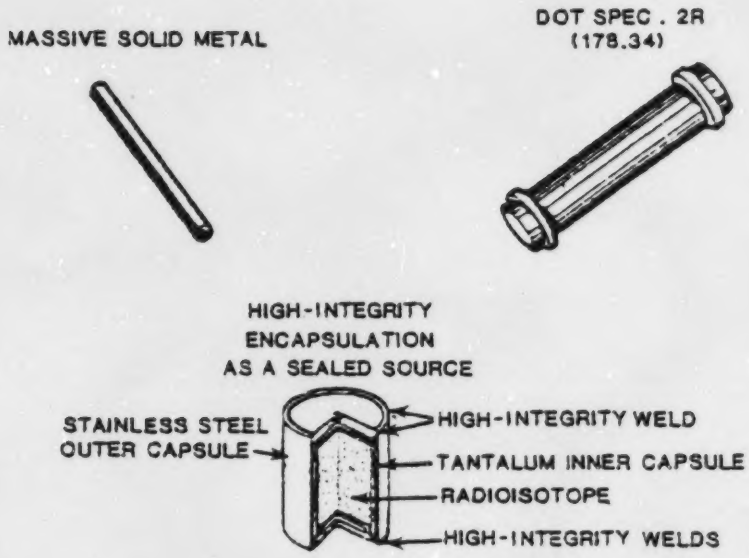


Figure 21-6-3. Special-Form Materials.

Normal-Form Material (Figure 21-6-4) is, simply, any material that does not qualify as Special Form.

WASTE MATERIAL IN PLASTIC BAG

LIQUID IN BOTTLE WITHIN METAL CONTAINER. NO FIRE RESISTANCE

POWDER IN GLASS OR PLASTIC BOTTLE

LOW MELTING. COMBUSTIBLE AND/OR FRANGIBLE SOLID

Figure 21-6-4. Normal Form Materials.

TYPE OF MATERIAL

RAM also is classified according to its type. Normal-Form Material is placed into one of seven transport groups that are ranged according to their radiotoxicity and their relative potential hazard in transportation. Transport group VII contains the least toxic material; group I the most toxic. Regulation 49CFR §173.390 lists the transport groups assigned to radionuclides. When radionuclides are mixed, special procedures, outlined in the same paragraph, are utilized in their classification.

RAM is assigned a Fissile Class in order to provide nuclear criticality safety. Fissile radioactive material is classified into one of three classes discussed later in the module.

TYPE "A" AND TYPE "B" QUANTITIES

The packaging requirements for RAM are structured around the total quantity of material in a package. This quantity usually is expressed in curies, millicuries, or microcuries. Table 21-6-2 relates quantities to packaging requirements.

TABLE 21-6-2
TYPE "A" AND TYPE "B" PACKAGE QUANTITY LIMITS

Transport Group	Type A Quantity (Curies)	Type B Quantity (Curies)
I	0.001	20
II	0.05	20
III	3	200
IV	20	200
V	20	5,000
VI, VII	1,000	50,000
Special Form	20**	5,000

Type "A" quantities can be placed in Type "A" packages; Type "B," in Type "B" packages. A 0.05-curie amount of a transport group II material, for example, would be classified as a Type "A" quantity and packaged in a Type "A" package.

Figure 21-6-5 illustrates some typical Type "A" packaging schemes. Type "A" packaging must be able to withstand "normal" conditions of transport. These "normal" conditions are defined; standards for Type "A" packaging are found in 49CFR §173.398(b). Type "A" packages also have to meet the standards for all packages (§173.24) and for specification 7A; general packaging Type "A" §173.350.

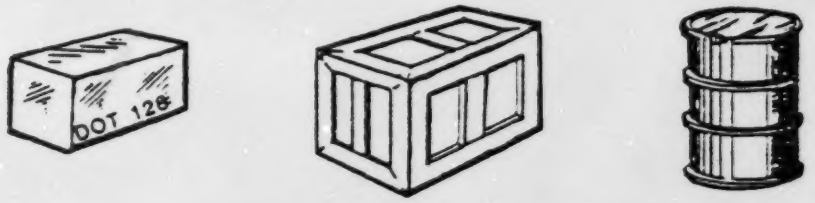


Figure 21-6-5. Typical Type "A" packaging.

Type "A" packaging does not require specific prior approval by DOT, but the shipper of these packages must maintain a certification and safety analysis on file for at least one year.

Type "B" packages must be able to withstand both normal and accident test conditions without loss of contents (Figure 21-6-6). The performance criteria used to test Type "B" packaging are set out in §173.398(c). They include the following:

- A 30-foot free drop onto an unyielding surface.
- A puncture test, which consists of a free drop over 40 inches onto a six-inch diameter steel pin.
- Thermal exposure at 1475°F for 30 minutes.

- Water immersion for eight hours (for fissile-materials packaging only).

All Type "B" packaging designs require prior approval of the U. S. NRC.

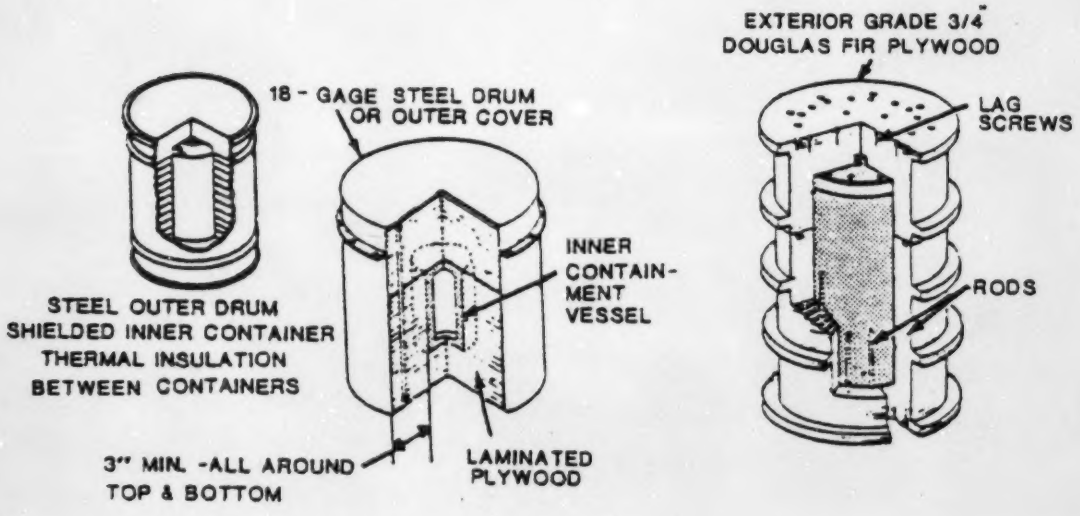


Figure 21-6-6. Typical Type "B" packaging.

LARGE QUANTITIES

Quantities that exceed Type "B" are "Large Quantity" RAM. The most common materials involved as large quantities are the high-curie irradiator sources and irradiated fuel materials. Packaging requirements for these sources involve all the Type "B" packaging requirements, plus provisions for decay-heat dissipation, heavier shielding, and other requirements (§173.395[c]).

SMALL QUANTITIES

Table 21-6-3 lists the activity limits for a material to be qualified as a Small Quantity (also called "Limited," or "Exempt") Material. If a RAM is classified as a Small Quantity, it may be sent by mail and is exempt from general packaging requirements in §173.393 if certain procedures are followed. Small-Quantity Materials must meet the packaging requirements set down in §173.391.

TABLE 21-6-3

ACTIVITY LIMITS FOR SMALL QUANTITIES, MANUFACTURED ARTICLES, RADIOACTIVE DEVICES, AND LOW-SPECIFIC-ACTIVITY MATERIAL

Transport Group	Small or Exempt Quantities	Manufactured Articles and Radioactive Devices Maximum Quantities		Low-Specific-Activity Materials
		Per Device	Per Package	
I	0.01 mCi	0.0001 Ci	0.001 Ci	0.0001 mCi/g
II	0.1 mCi	0.001 Ci	0.05 Ci	0.005 mCi/g
III	1 mCi	0.01 Ci	3 Ci	0.03 mCi/g
IV	1 mCi	0.05 Ci	3 Ci	0.3 mCi/g
V	1 mCi	1 Ci	1 Ci	
VI	1 mCi	1 Ci	1 Ci	
VII	25 Ci	25 Ci	200 Ci	
Special Form	1 mCi	0.05 Ci	20 Ci	

Table 21-6-3 also lists activity limits for manufactured articles and radioactive devices such as clocks, instruments, and electronic devices that are exempt from

packaging requirements, provided they meet criteria in §173.391(b).

Low-Specific-Activity Materials are uranium or thorium ores, tritium oxide, and other materials in which the activity is more-or-less uniformly distributed and in which the average estimated concentration per gram does not exceed the specification of §173.389(c).

TRANSPORT INDEX

The Transport Index (TI) is utilized in the computation of the number of packages that may be included in one shipment. This number is placed on the package label to designate the degree of control to be exercised by the carrier during transportation.

The TI is a carefully-computed safety indicator – a measuring unit that takes into account several different factors. For instance, a TI of 1 is assigned to a package that emits a radiation dose of 1 mrem per hour at a distance of 3 feet from its surface, and the TI for any other package varies in proportion to the dose at that standard distance. Thus, a dose of 10 mrem/hr at that point raises the TI for the package to 10; a dose of half a millirem per hour indicates that the TI is 0.5. These indexes are the radiation TI of a package.

Since some nuclear materials are capable of sustaining a nuclear chain reaction, some additional form of control is desirable to ensure that a number of packages that contain these fissile isotopes will not be assembled in one place and thereby produce a critical mass and geometry.

A criticality TI, therefore, may be assigned on the basis of amount, nature, and purity of the fissile material involved; allowances are made if neutron-absorbing material has been incorporated to discourage chain reactions.

The assignment of a criticality TI is a complicated procedure, but the net result is that if the total TI for any vehicle or storage area is 50 or less, there will be an adequate safety margin to avoid any chain reaction.

The radiation TI and the criticality TI rarely will be identical; and when they differ, the package in question always is assigned the larger of the two numbers for shipping purposes. This procedure ensures safety.

The TI of each package must be noted on its warning label, and each package must bear at least two of these labels on its opposite sides.

The maximum limits of radiation for a shipment depend upon the conditions under which the material is transported. Ordinarily, the radiation at the surface of any package is limited by DOT regulations to no more than 200 mrem/hr at 3 feet from the surface of any single package. The normal limit is 10 mrem/hr, which equals a TI of 10.

A TI of only 10 would be very difficult to achieve with a spent fuel cask; therefore, such a shipment is made upon a "sole-use" basis. Thus, when the spent fuel cask is shipped within a closed truck or rail car, the main body of the vehicle itself becomes the "package." The radiation level of the vehicle then must not exceed 200 mrem/hr at its surface.

STOWAGE CONTROL

The TI acts to ensure safety and to provide a format for stowage control (Table 21-6-4) by establishing the distances that must be maintained between the RAM and people, animals, and photographic film.

TABLE 21-6-4
STOWAGE CONTROL FOR RAIL SHIPMENTS

Total Transport Index	Minimum Separation Distance in Feet to Nearest Undeveloped Film	Minimum Distance in Feet to Area of Persons, or Minimum Distance in Feet from Dividing Partition of a Combination Car
None	0	0
0.1 to 10.0	15	3
10.1 to 20.0	22	4
20.1 to 30.0	29	5
30.1 to 40.0	33	6
40.1 to 50.0	36	7

Table 21-6-4 establishes stowage control for rail shipments (§174.700). Tables for other modes of transportation are found in §175.00, §176.700, and §177.842(b).

The TI system, together with tables of separation distances, provides a system whereby the carrier can exercise control over the amount of radiation to which package-handling personnel and other passengers may be exposed.

FISSILE CLASSES

The classification of fissile materials is based upon the TI system:

- FISSILE CLASS I are packages that may be transported in unlimited numbers and in any arrangement, and that require no nuclear criticality safety controls during transportation. For purposes of nuclear criticality safety control, a Transport Index is not assigned to Fissile Class I packages; however, the external radiation levels may require a Transport Index number.
- FISSILE CLASS II packages may be transported together in any arrangement but in numbers that do not exceed any aggregate transport index of 50. For purposes of nuclear criticality safety control, individual packages may have a Transport Index of not less than 0.1 and not more than 10, although the external radiation levels may require a higher Transport Index number (but not to exceed 10). Such shipments require no nuclear criticality safety control by the shipper during transportation.
- FISSILE CLASS III consists of packages that do not meet the requirements of Fissile Class I or

II and that are controlled to provide nuclear criticality safety in transportation by special arrangements between the shipper and the carrier.

Nuclear criticality safety controls are specified by ERDA (now DOE) Manual Chapter 0530.

WARNING LABELS

Each package of radioactive material, unless exempt, must be labeled (§172.403[f]) on two opposite sides, with a distinctive warning label. Each of the three label formats, as described in §172.436 through 172.400 and Figure 21-6-7, bears the unique trefoil symbol.

Figure 21-6-7. Package labels (a), (b), and (c).

These labels alert persons handling packages that the package may require special handling. If the background color of the label is all white (a "white-labeled package"), the radiation is minimal; and nothing special is required for that package. If, however, the background of the upper half of the label is yellow (a "yellow-label package"), a radiation level that requires consideration may exist at the outside of the package; and an indication of what controls must be exercised for that package is related to the Transport Index concept. If the package bears a yellow label having three stripes, the rail or highway vehicle in which it is carried must be placarded. (A placard is simply a sign placed on a vehicle.) The criteria that must be considered by the shipper in choosing the appropriate label are listed in Table 21-6-5. Specific labeling requirements for RAM are given in §172.403.

TABLE 21-6-5

RADIOACTIVE MATERIAL PACKAGES LABELING CRITERIA
DOSE RATE LIMITS

Label	At Any Point on Accessible Surface of Package	At Three Feet From External Surface of Package (Transport Index)
"Radioactive-White I"	0.5 mR/h	0
"Radioactive-Yellow II"	50 mR/h	1.0 mR/h
"Radioactive-Yellow III"*	200 mR/h	10 mR/h

* Requires vehicle placarding
(This label is mandatory for any Fissile Class III (173.389A) or large quantity package (173.389B), regardless of dose rate levels.)

SHIPPER AND CARRIER REQUIREMENTS

Responsibilities for the packaging and the transporting of RAM may be separated into shipper and carrier requirements.

In general, the shipper is responsible for the following tasks:

- Determine package requirements.
- Package materials.
- Determine TI of materials.
- Label materials and mark packages.
- Complete shipping papers.
- Submit shipper's certification.
- Apply security seal.

The carrier must perform the following tasks:

- Obtain certificate from shipper.
- Apply appropriate placard to vehicle.
- Provide stowage control using TI.
- Report all incidents (fire, accident, etc.).
- Carry all shipping papers.

Some of these responsibilities require additional classification and explanations.

SHIPPING PAPERS AND CERTIFICATION

Certain essential elements of information must be included on the shipping paper description (§172.203[d]). These requirements also apply to packages that contain small quantities and to radioactive devices (§173.391).

The shipping papers must include a shipping certification signed by the shipper.

The following certification statement has been required by Section 172.204(a) since July 1, 1979.

> "This is to certify that the above-named materials are properly classified, described, packaged, marked and are in proper condition for transportation according to the applicable regulations of the Department of Transportation."

SECURITY SEAL

The outside of each radioactive material package must incorporate a security seal, which is not readily breakable and which, while intact, will be evidence that the package has not been illicitly opened (§173.393[b]).

PLACARDING

The carrier must apply the appropriate placard (Figure 21-6-8) on the rail or highway transport vehicle if any RAM package on board bears the "Radioactive YELLOW-III" label (§174.541[b]). When the vehicle is carrying fissile or low-specific-activity uranium hexafluoride, a radioactive placard must be placed on the vehicle. If the vehicle is carrying more than 1,000 lb of this material, a CORROSIVE placard also must be affixed. Placards must be positioned on each side and each end of a vehicle. Requirements for placards are found in §172.50 through §172.558.

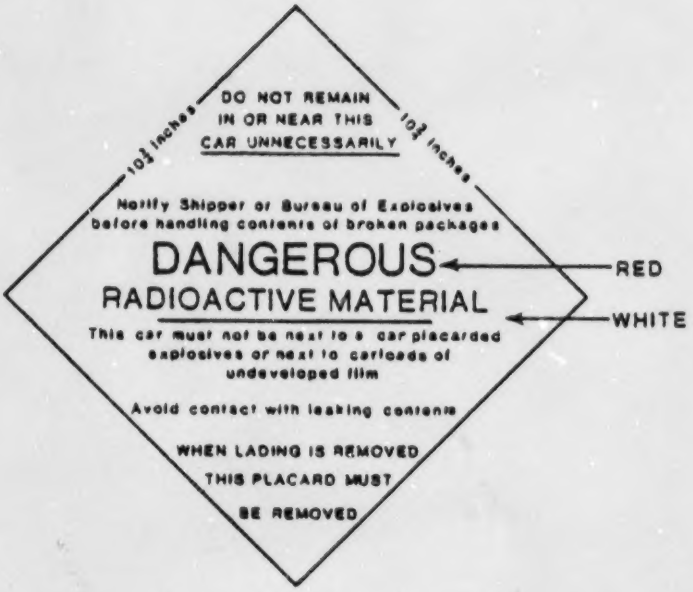


Figure 21-6-8. Typical vehicle placard (rail shipments).

THE REPORTING OF INCIDENTS

The carrier, at the earliest practicable moment, must notify the shipper and DOT if fire, breakage, spillage, or suspected radioactive contamination occurs during shipment of radioactive material. Vehicles or buildings in which contamination occurs may not be used again until the dose rate on any surface is less than 5 millirem per hour and until there is no removable radioactive contamination.

If radiological advice or assistance is needed, DOE should be notified. Technical assistance may be obtained by calling the regional office of the Interagency Radiological Assistance Plan. A detailed hazardous-material incident report must be filed after the incident. Paragraphs 171.15, 171.16 and 174.750 outline these procedures.

DETERMINATION OF SHIPPING REQUIREMENTS

Use the below step-by-step procedures to determine the shipping requirements for RAM:

1. Determine proper name of radionuclide from listing §173.390. Note transport group of radionuclide.
2. Determine if RAM will be shipped as Special- or Normal-Form Material.
3. Determine whether material is fissile or nonfissile.
4. Determine quantity of material:

   Consult table §173.391 to determine if RAM is Type "A," Type "B," or Large-Quantity Material.

   If RAM cannot be classified as any of the quantities above, consult §173.391 to determine if RAM is Limited Quantity.

   Consult §173.389(c) to determine if RAM is a Low-Specific-Activity Material.

   Determine if material is manufactured article or radioactive device.
5. Locate shipping name of material in Hazardous Materials Table (§172.101). If material is not specifically named, look under the general heading of "Radioactive Material." Thorium, plutonium, and uranium metal and its compounds are the only RAM specifically listed in the Table. All RAM not listed specifically must be classified under one of the six "Radioactive Material" headings.
6. From the "Hazardous Materials Table," determine labels required, packaging exceptions, and specific requirements.

7. Follow the specific labeling and packaging requirements for the material, and follow all applicable general labeling and packaging requirements. Part 172 specifies all general marking, labeling, and placarding requirements. Paragraph 172.310 gives specific marking requirements for RAM; §172.403 gives specific labeling requirements. (Subpart C, Part 172, specifies requirements for shipping papers. Security-seal requirements are outlined in §173.393.)

DETERMINATION OF CARRIER REQUIREMENTS

Use the step-by-step procedures listed here as a guide for the determination of carrier requirements.

1. Determine mode of transportation.
2. Obtain shipping papers and certification from shipper (Part 172).
3. Apply appropriate placard to vehicle (§172.504 through Appendix C, Part 172).
4. Provide general and stowage control using TI for —
   - Carriage by rail: consult Part 174 for general requirements and §174.700 for stowage requirements.
   - Carriage by aircraft: consult Part 175 for general requirements and §175.700 for stoward requirements.
   - Carriage by vessel: consult "Water Shipments" section of Hazardous Materials Table (§172.101). Read §172.100(h) for explanation of symbols. Part 176 provides general requirements; §176.700, stowage requirements.

- Carriage by public highway: consult Part 177 for general requirements and §177.842 for stowage requirements.

5. Report all incidents (§171.15, 171.16, and 174.750).

EXERCISES

Use 49CFR to find the following information about the radioactive material listed below.

- Transport group.
- Whether material is fissile or nonfissile.
- Whether material is Type "A," Type "B," "Small-Quantity," "Large-Quantity," or "Low-Specific Activity" Material.
- Proper shipping name.
- Hazard class.
- Labels required.
- Paragraph references for packaging exceptions and special requirements.

1. 18 Ci of strontium-90 in normal form.
2. 5 Ci of germanium-71 in normal form.
3. 25 Ci of tritium in normal form and absorbed in solid material.
4. 4 Ci of radium-224 in normal form.
5. 50 milliliters of tritium oxide in aqueous solution with a concentration of 4 millicuries per milliliter in normal form.
6. 30 Ci of tritium-190 in special form.

Use 49CFR and –

7. Find the minimum separation in feet of an area occupied by persons from a package of Radioactive Yellow II material having a Transport Index of 10.7. The package is stowed in a railroad car.
8. Find the minimum separation in feet from a regularly-occupied working space and 10 packages of Radioactive Yellow III material that have a total Transport Index of 28. The material is surrounded by 2 feet of cargo. There is one steel bulkhead between the material and the working space. The material is transported by an ocean-going vessel.

MATERIALS

1 copy of "Title 49, Code of Federal Regulations, Parts 100 to 199."
1 dummy shipping vial, marked "3 Ci Molybdenum-99."
1 dummy Type "A" shipping package.
1 dummy Type "B" shipping package.
Assorted Radioactive White," "Radioactive Yellow II," and "Radioactive Yellow III" labels.
Wrapping paper.

Situation: A 3-Ci normal form quantity of molybdenum-99 must be shipped to Kranktown General Hospital, Kranktown, Texas. The shipper is Diversified Atomics Inc., located at 666 Jonesberg Drive, Doeboro, Oklahoma. The molybdenum will be shipped by air and then delivered by truck. The dose, 3 ft from the surface of the package, is 0.01 millirem per hour. The package will not be shipped with other RAM.

1. Use 49CFR and the information above to complete items 1 through 7 of Data Table 21-6-1.
2. By using the completed Data Table and laboratory materials provided and by consulting 49CFR whenever necessary, prepare a dummy shipping package for the 3-Ci quantity of molybdenum-99.
   a. Determine TI of package, and enter in Data Table 21-6-2.
   b. From references cited in items 2 through 5, select, mark, and label package.

DATA TABLE 21-6-1

1.	Proper Shipping Name	
2.	Transport Group	
3.	Fissile Material? If so, the class	
4.	Type Material "A"	
	"B"	
	Small-Quantity	
	Large-Quantity	
	Low-Specific-Activity	
5.	Hazard Class	
6.	Labels required	
7.	Paragraph references for packaging exceptions and special requirements	

DATA TABLE 21-6-2

1.	Transport Index – 173.389 Ci _____	
2.	Quantity Type:	
	Limited Quantities	173.391(a)
	Radioactive Devices . . .	173.391(b)
	Type A	173.389(1)
	Type B	173.389(1)
	Large Quantities	173.389(b)
3.	Packaging: General packaging and shipping requirements 173.393 _____	
	Fissile, Radioactive Material . . .	173.396
	RAM Devices	173.391(b)
	RAM Low-Specific-Activity (L.S.A.)	173.392(a), 173.395
	RAM N.O.S.	
	– Type A Quantities	173.395(a)
	– Type B Quantities	173.395(b)
	– Large Quantities	173.395(c)
	RAM Special Form	173.394
	RAM Limited Quantities	173.391(a)
4.	Marking (dual marking if RAM is also some other hazard)	172.300, 304, 306, 310
5.	Labeling (2 labels placed on opposite sides of package)(dual labeling if RAM is also some other hazard) . . .	172.400(a), 172.402(a)(1), (b), 172.403, 172.406(c), (e)(1)

White Label I:	Maximum 0.0 TI
Yellow Label II:	Maximum 1.0 TI
Yellow Label III:	Maximum 10.0 TI

Gibson, R. The Safe Transport of Radioactive Materials. Long Island City, NY: The Pergamon Press, Inc., 44-01 21st St., 1966.

IAEA Regulations for the Safe Transportation of Radioactive Materials. New York: Unipub, Inc., P. O. Box 443.

"Radiological Emergency Operations-Instruction Manual." Springfield, VA: National Technical Information Service.

"Radiological Emergency Operations-Students Manual." Springfield, VA: National Technical Information Service.

Shipping Radioactive Materials. San Francisco: Bechtel Corporation.

"Summary of Federal Regulations for Packaging and Transportation of Radioactive Materials." Springfield, VA: National Technical Information Service, 1971.

1. Write definitions for the following terms:

Tariff.

Normal-Form-Material.

Special-Form-Material.

Transport Group.

Large-Quantity Material.

Limited-Quantity Material.

Type A Quantity.

Type B Quantity.

Type A Packaging.

Type B Packaging.

Small-Quantity Material.

Low-Specific-Activity Material.

Transport Index.

Fissile Class I, II and III.

Yellow Labeled Package.

White-Labeled Package.

Shippers Certification.

Sole Use.

IAEA Regulations.

Placarding.

Stowage Control.

Security Seals.

2. What entries must be made in the shipping papers that accompany RAM? Use 49CFR and list at least three.

3. What steps should be taken when an accident causes suspected contamination while RAM is being transported?

4. In 49CFR locate the following information about the radioactive material listed below.

   - Transport Group.
   - Whether material is fissile or nonfissile.
   - Whether material is Type "A," Type "B," "Small-Quantity," "Large-Quantity," or "Low-Specific-Activity" material.
   - Proper shipping name.
   - Hazard class.
   - Labels required.
   - Paragraph references for packaging exceptions and special requirements.

   a. 18 Ci ^{234}U in normal form.

   b. 30 Ci neptunium-237 in normal form.

   c. 2,000 Ci strontium-90 in special form.

5. Ten packages of radioactive II RAM having a total TI of 30 are stowed in the cargo hold of an aircraft. Determine the minimum distance in feet from the packages to the dividing partition of the cargo compartment.

NUCLEAR TECHNOLOGY

MODULE 21 - 7

LEAK TESTS OF SEALED RADIOACTIVE SOURCES

RADIOACTIVE MATERIALS DISPOSAL
AND MANAGEMENT

COURSE 21

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

COURSE 21 RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT

MODULE 21-1 Radioactive Waste Disposal Procedures

MODULE 21-2 Routine Sampling of Radioactive Waste

MODULE 21-3 Radioactive Waste Disposal Regulations

MODULE 21-4 Measurement of External Radioactive Contamination

MODULE 21-5 Regulations for Transportation of Radioactive Materials

MODULE 21-6 Packaging and Monitoring of Radioactive Materials for Shipment

MODULE 21-7 Leak Tests of Sealed Radioactive Sources

Copyright© 1980

Center for Occupational Research and Development, Incorporated
4800 Lakewood Drive, Waco, Texas 76710

Reproduction or publication of the content in any manner, without the express permission of the Center for Occupational Research and Development, Incorporated, is prohibited. No liability is assumed with respect to the use of the information herein.

INTRODUCTION

A sealed source is radioactive material that has been encapsulated and sealed to prevent its inadvertent release. Sealed sources have many uses in research, in industry, in medicine, and even in agriculture. The radiation emanating from them can be employed to irradiate cancerous infestations, to detect smoke in a burning building, to calibrate instruments, to gage the thickness of metal, and to make clock dials glow in the dark.

The radioactive material itself must not escape from its sealed capsule. Federal requirements specify the integrity of containment for each quantity and type of radioactive material. These regulations also specify how often each type of sealed source must be leak tested to assure integrity. A license must be issued before these sources can be employed. This license, called the "user's license," further specifies regulations for the use and storage of these sources.

This module introduces some of the uses of sealed sources and explains the procedures for leak tests.

MODULE PREREQUISITES

The student should have completed a course in basic algebra; Course 1, "Radiation Physics"; Course 2, "Radiation Protection I"; Course 11, "Radiation Detection and Measurement"; Course 17, "Radiation Protection II"; and Course 20, "Radiation Monitoring Techniques."

OBJECTIVES

Upon completion of this module the student should be able to:

1. Describe the methods for leak testing:
   - A low-energy beta source.
   - A high-energy gamma source (cobalt-60 medical irradiator).
   - A radium source.
2. Given the results of a wipe test performed on a sealed source, calculate the maximum activity in disintegrations per minute (dpm), and convert to microcuries.
3. Cite the number and part of the federal regulation that specifies licensing requirements and procedures for the handling and the testing of sealed sources.
4. State at least one use for the following types of sources:
   - Alpha source.
   - Low-energy beta source.
   - High-energy beta source.
   - Gamma source.
   - Neutron source.
5. Correctly perform a leak test and determine the level of activity on each of the following sources:
   - Low-energy beta source such as a laboratory beta standard.
   - High-level gamma source.
   - Radium source.

TYPES OF SEALED SOURCES

Sealed sources must prevent the inadvertent release of radioactive material. They are classified according to the type of radiation that emanates from them and the geometry of their radiation fields. There are alpha, beta, gamma, and neutron sealed sources; and, aside from small microcurie sources used for instrument checks, sealed sources are relatively high in source strength. The amount from a few millicuries to curies is enough for such operations as instrument calibration and thickness gages; while a few hundred curies are needed for industrial radiography; and as much as several megacuries may be required in some phases of nuclear medicine.

ALPHA SOURCES

Alpha sources are utilized chiefly in the ionization of a small volume of air. Sources such as ^{210}Po and ^{241}Am, for example, can remove static electricity from the paper of a high-speed printer if placed near the paper as it exits the printer. The alpha particles cause ionization in the air, thereby neutralizing the static electricity on the paper.

Fire alarms, such as the smoke detectors available for the home, function because of the high interaction capability of alpha particles. When smoke particles and vapor fill the void between a source and a detector, the intensity change of the alpha particles electrically triggers an alarm.

Alpha particles have a very short range, and the radioactive material that produces them usually is not encapsu-

lated. It normally is electrodeposited in such a manner that it adheres strongly to a surface treated as a sealed source. Because excessive wiping of the surface may dislodge some radioactive material, care must be taken when these alpha sources are tested.

BETA SOURCES

Beta particles have a range of several feet in the air, but can be stopped by a thin sheet of aluminum or equivalent material.

Both low- and high-energy beta sources are employed. Tritium, carbon-14, polonium-147, and strontium-90 are among the more common beta emitters. Low-energy beta emitters such as ^{3}H, ^{14}C, and ^{147}Pm function well as luminescent sources for clock and instrument dials. These beta particles have a very short range, and in their analysis a sensitive detector with appropriate geometry is required for the production of as accurate a count estimation as possible.

Sealed sources with high-energy beta emitters as ^{90}Sr are utilized to gage the thickness of metal foil as it is being rolled.

Since beta particles can be stopped rather easily, sealed beta sources are equipped with exit ports covered by a thin "window." The window usually is fragile, and care must be taken to avoid rupturing it and, consequently, releasing the radioactive materials contained inside.

GAMMA SOURCES

Gamma radiation is of a highly penetrating electromagnetic type. The radioactive material of a sealed gamma source (such as cobalt-60) decays by beta-gamma emission. The sealed source container cover is thick enough to prevent the beta particles from escaping but allows gamma radiation to escape. Personnel must be shielded from gamma sources with strengths of 0.1 mCi and over.

Sealed gamma sources are employed in industrial radiography for the nondestructive testing of wells and the internal inspection of thick pieces of metal pipe and metal plates. These sources have strengths of up to 100 curies; therefore, care must be taken to avoid personnel exposure.

Medical facilities use sealed sources that have strengths that range up to several megacuries of ^{60}Co for the therapeutic treatment of some malignant tumors. These sources always are heavily shielded.

NEUTRON SOURCES

When an alpha-emitting material is placed near low-atomic-number elements, neutrons are produced. Neutron sources such as plutonium-beryllium, americium-beryllium, and radium-beryllium produce the nuclear reaction given by Equation 21-7-1.

$$^{4}_{2}\alpha + ^{9}_{4}Be \longrightarrow 2\ ^{6}_{3}Li + ^{1}_{0}n \qquad \text{Equation 21-7-1}$$

(Equation = Eq.)

Neutron sources, which vary in strength from a few millicuries to several curies, are applied in technology in a number of interesting ways, including these:

- Well logging, or the analyzing and the recording of the character of geological formations penetrated by a drill hole. The process determines the amount of hydrogen (and, hence, water) contained in subsurface strata.
- Neutron radiography of hydrogenous material.
- Neutron absorption experiments.
- Calibration of instruments.

SAFETY

Because sealed sources are normally high-activity sources, special attention must be paid to the dose received by personnel while handling and working around them. Exposure is kept to a minimum by the use of shielding, by remote handling tools, and by following prescribed safety procedures.

REGULATION

Regulatory requirements for the handling and testing of sealed sources are specified by 10CFR (Code of Federal Regulations), Parts 20, 31, and 34. Any other requirements in regard to a specific radioisotope are defined in the user's license. These references should be consulted whenever there are any questions concerning the handling and testing of these sources. As a minimum, the regulations require a

leak test at least every six months. The equipment and procedure must be capable of detecting a leak of 0.005 microcuries or less. Personnel who perform a leak test must be qualified by education and training and must be listed on the license or have a license issued them by the regulatory agency.

LEAK TESTING

DIRECT TESTING

Low-to-intermediate sources (those less than a few millicures) can be handled with remote handling tools and directly tested for leaks. The source is wiped with a piece of filter paper or other smear blank material. This material either is held in a pair of tongs and smeared over an area of 100 cm^2 of the fixed source, or the smear blank itself is held in place and the source wiped on it. An analysis of the smear then is performed. Because of the low levels of radiation present, there is usually no permanent shielding set up for this procedure. Thus, the person performing the test must rely on distance and/or temporary shielding (sometimes called "shadow" shielding) for radiological protection. A typical shadow shield might consist of a few blocks of lead placed between the source and a person.

INDIRECT TESTING

Exposure to high-level sources that would result in high doses of radiation during the wipe test requires an indirect means of detection for the release of radioactive material. To use this indirect method, the technician remotely transfers the source to a temporary shield area and checks the original holder for contamination by smearing the surfaces near the point at which the source usually is located. The "S" tube is smeared when the source capsule is removed.

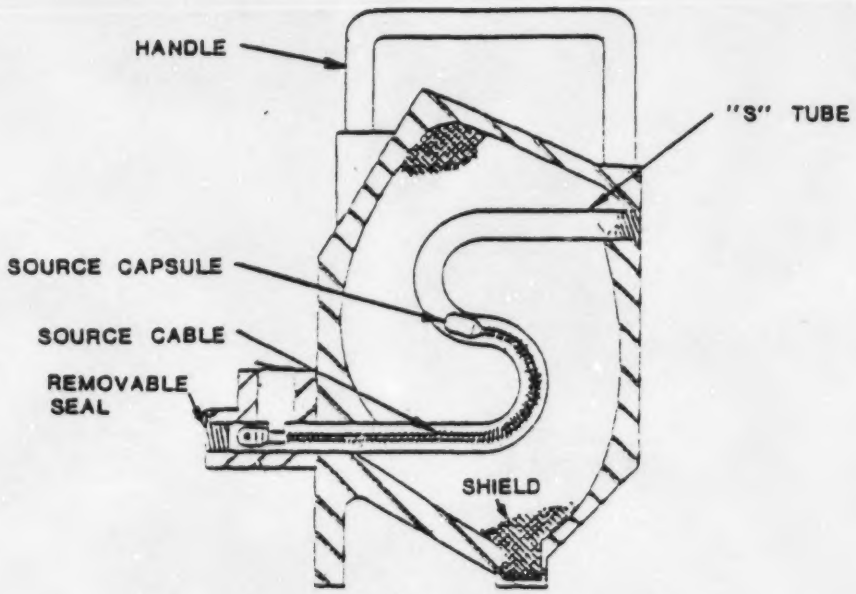


Figure 21-7-1. High-level storage system (cutaway view).

TESTING GASEOUS SOURCES

Gaseous sources such as krypton can be leak tested if a small sample of air is drawn from around the proximity of the source. This gas sample can be trapped and transferred to the laboratory for analysis or analyzed directly through a radiation detector designed to detect radioactive gases.

Sources, such as radium, that have gaseous radioactive daughters (radon) also can be leak tested. In the case of radium sources, the radium decays to radon gas. This daughter product gas is radioactive and easily can escape into the atmosphere. Radon gas, however, decays into radioactive particulate material which can be collected on a filter by conventional air-sampling methods. The filter then is analyzed for evidence of a leak in the source container indicated by the presence of particulate decay products of radon.

ANALYSIS

Immediately after a source has been smear sampled, the smear blank should be checked with a portable radiation detector to determine if a high level of radiation is present. Portable monitoring equipment can be designed and calibrated to perform a preliminary analysis to a level of 0.005 microcuries. If the leak test indicates the presence of 0.005 microcuries or more, the source will be taken out of service and the appropriate authorities notified.

Analysis performed with portable radiation detection equipment is only a rough analysis. A more precise analysis usually is performed with a more sensitive counter/scaler system, in which the detector efficiency (counts per radiation emitted) is predetermined for the isotope of interest and the counting geometry under use. Background radiation and the radiation of the sample are measured by the laboratory scaler/counter. The Equation 21-7-2 count rate in counts per minute is calculated from

$$\text{Net Count Rate} = \text{Sample Count Rate} - \text{Background Count Rate}$$

$$n_x = n_s - n_b \qquad \text{Eq. 21-7-2}$$

Disintegrations per minute then are calculated by use of Equation 21-7-3.

$$\text{Disintegrations per minute} = \frac{\text{Counts per minute}}{\text{Counter efficiency}}$$

$$dpm = \frac{cpm}{E_i} \qquad \text{Eq. 21-7-3}$$

Disintegrations per minute may be converted to microcuries: One microcurie equals 2.22×10^6 dpm.

Normally, if a leak test determines the presence of 0.005 μCi or more the source will be taken out of service.

Equations 21-7-2 and 21-7-3 are clarified in the accompanying example.

EXAMPLE

Given: A wipe of an irridium-92 source was counted in a laboratory scaler/counter with the following results:

counter efficiency (E_i) = counts/disintegration

counter background (n_b) = 25 counts per minute (cpm)

sample count (n_s) = 36 cpm

counting time (c_t) = 1 minute

Find: Net activity in microcuries.

Solution:

$$\text{Net Count} = \text{Sample Count Rate} - \text{Background Count Rate}$$

$$n_x = n_s - n_b \qquad \text{Eq. 21-7-2}$$

$$= 36 - 25$$

$$n_x = 11 \text{ cpm.}$$

$$\text{Disintegrations per minute} = \frac{\text{Counts per minute}}{\text{Counter efficiency}}$$

$$dpm = \frac{cpm}{E_i} \qquad \text{Eq. 21-7-3}$$

$$= \frac{11 \text{ cpm}}{0.1 \text{ counts/disintegration}}$$

dpm = 110 disintegrations per minute.

Convert to microcuries.

$$\text{Net Activity} = \frac{110 \text{ cpm}}{2.22 \times 10^6 \text{ dpm}/\mu\text{Ci}}$$

$$= 5.0 \times 10^{-5} \ \mu\text{Ci}$$

The integrity of the source is intact.

Since a net activity of only 5.0×10^{-5} μCi was detected for the irridium-92 source its integrity should be considered intact.

SUMMARY

There are two general kinds of leak testing: direct and indirect. Direct testing is employed for low-to-intermediate energy sources; indirect testing, for high-energy sources. Exposure to these sources would result in high doses of radiation if personnel were exposed to them during the wipe test.

Special procedures are utilized for the testing of sources. Small samples of air are drawn from around the

proximity of the source and either transferred to the laboratory for analysis or transferred directly through a radiation detector especially designed for the detection of radioactive gases.

Regardless of how a sample is obtained, it must be analyzed as soon as possible. A rough analysis can be performed with portable monitoring equipment; a more precise analysis then can be performed with a sensitive counter/scaler system. When the counter efficiency, counter background, sample count, and counting time are known, the net activity of a source can be determined from Equations 21-7-2 and 21-7-3.

EXERCISES

1. A wipe obtained from a sealed source was counted with the following results:

   Counter efficiency = 0.1.
   Background = 30 cpm.
   Sample - 49 cpm.

   Calculate the maximum activity in dpm, and convert to microcuries.

2. Describe how a leak test on a therapeutic medical irradiator that contains several megacuries of cobalt-60 should be performed.

3. Describe how the following sources should be leak tested:

   Laboratory beta source.

   High-level gamma source.

   Gaseous source.

MATERIALS

1-to 50-μCi $^{90}Sr/^{90}Y$ source.
Tongs or other remote handling tools.
Filter paper or other swabbing/wiping material.
1 proportional or GM detector.
1 counter/scaler.
1 sample holder or planchet.
1 portable GM survey meter.

PROCEDURES

THE WIPE TESTING OF A LOW-LEVEL BETA SOURCE

1. Check out instruments to ensure that they are working properly. Determine background counts per minute with GM survey meter. Record results in Data Table 21-7-1.
2. Use portable survey meter to determine net activity of source. Record results.
3. Hold source in rigid position. Attach filter paper to tongs, and gently wipe the surface of the source.
4. Measure activity of wipe with portable survey meter. Record results. Determine net activity of wipe. Use Equation 21-7-2.
5. If wipe does not show appreciable activity, place filter paper into sample holder or planchet, and place in laboratory counter.
6. Preset timer for 5 minutes. Record count, counting time, and counts per minute in Data Table 21-7-2.

7. Obtain predetermined value for efficiency of the detector. From this value and other data obtained, calculate the activity of the wipe in microcuries. Use Equation 21-7-2.
8. Does source comply with applicable regulations for integrity?

DATA TABLE 21-7-1
PORTABLE SURVEY METER

cpm from background	
cpm from source	
Net cpm	
cpm from wipe	
Net cpm from wipe	

DATA TABLE 21-7-2
LABORATORY COUNTER-ACTIVITY OF WIPE

cpm from background	
cpm from source	
Net cpm	
Efficiency of detector	
Activity of wipe in μCi	

REFERENCE MATERIALS

Cember, Norman. Introduction to Health Physics. Exeter, Great Britain: Pergamon Press Ltd., 1969.

Moe, H.J.; Lusuk, S.R.; Schumacher, M.C.; and Hunt, H.M. Radiation Safety Technician Training Course. Report ANL-7292, Revision 1, prepared for Argonne National Laboratory, Argonne, IL. Springfield, VA: National Technical Information Service, U.S. Department of Commerce, 1972.

1. Describe the methods used for leak testing the following sources:

   A low-energy beta source.

   A high-energy gamma source.

   A radium source.

2. A wipe obtained from a sealed source was counted with the following results:

   Counter efficiency = 0.3.
   Background = 49 cpm.
   Sample = 51 cpm.

   Calculate the maximum activity in dpm, and convert to microcuries.

3. Write the number and parts of the federal regulation that specifies requirements and procedures for the handling and testing of sealed sources.

4. State at least one use for the following types of sources:

Alpha source.

Low-energy beta source.

High-energy beta source.

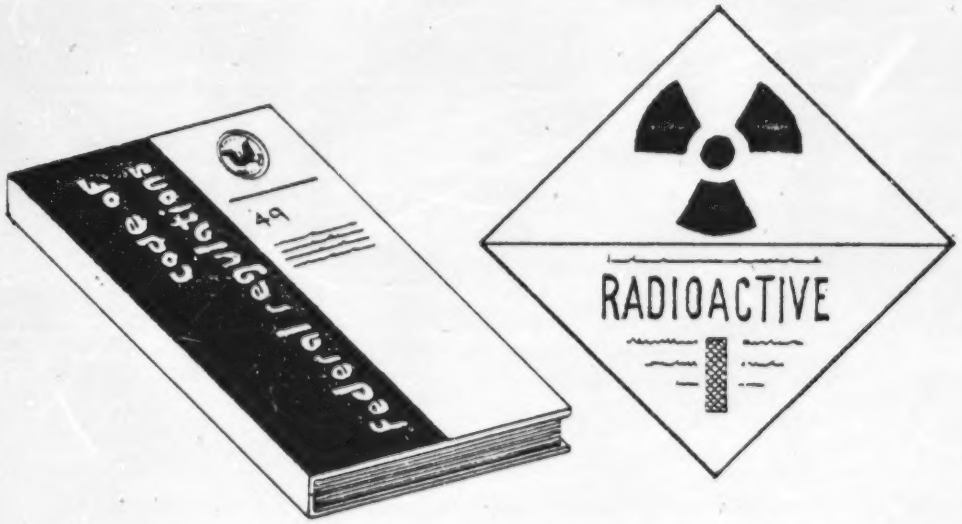
Gamma source.

Neutron source.

NUCLEAR TECHNOLOGY

INDEX

COURSE 21 - RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT



RADIOACTIVE MATERIALS DISPOSAL
AND MANAGEMENT
COURSE 21

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

NUCLEAR TECHNOLOGY SERIES

INDEX

for

COURSE 21, RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT (SEVEN MODULES)

NOTE: Each module in this Course is numbered separately, and the page numbers begin with page 1 in each module. Therefore, this Index lists for each entry the module number (underlined), followed by a comma and the page number. Figures and tables are listed by their numbers, followed by the module and page number in parentheses. A Master Index is available in a separate volume. This general index merges all index entries from the 35 Nuclear Courses. It is a valuable research tool, with which the student or researcher can locate all the references to any subject within the 35 Courses.

Absorption
  for gas sampling, 21-2, 12, 13
Activation product
  definition of, 21-1, 12
Aerosols
  classification of, 21-2, 9, 10
  definition of, 21-2, 8
Antarctica Treaty of 1959
  on radioactive waste, 21-3, 17
Atomic Energy Act of 1954
  waste management responsibility in, 21-3, 8
Atomic Energy Commission
  past waste regulations by, 21-5, 7

Carrier
  accident, 21-5, 26; 21-6, 24
  definition of, 21-5, 4
  delay of, 21-5, 26
  placarding of, 21-6, 23
  regulatory agencies for, 21-5, 5, 6
  requirements of, 21-6, 26, 27
  responsibilities of, 21-5, 25, 26; 21-6, 22
Code of Federal Regulations
  and sealed sources, 21-7, 6
  and waste, disposal, 21-1, 19-21; transport, 21-5, 9, 10
Commodities
  regulation, 21-5, 7
Compactors
  for solid waste, 21-1, 23, 24
Containers
  of radioactive waste, 21-5, 4
Contamination
  of container external, 21-4, 5, 6

Decay
  of radioactive material, 21-1, 5
Department of Defense
  and radioactive waste, 21-3, 7, 8
Department of Energy
  and waste, monitoring, 21-3, 23; regulation, 21-3, 4, 5; research, 21-3, 17, 18
Department of Transportation
  establishment of, 21-5, 9
  and waste, regulation, 21-3, 5; 21-5, 7, 8; safety regulations, 21-5, 6; transportation of, 21-5, 11-13

Energy Reorganization Act of 1974
  waste management responsibility in, 21-3, 7, 9, 17
Environmental Impact Statement
  requirement for, 21-3, 19
Environmental Protection Agency,
  radioactive standards by, 21-3, 11
  and waste, monitoring, 21-3, 23; regulation, 21-3, 5

Fissile materials
  classification of, 21-5, 4, 5
  list of, 21-5, 5.
Fission products
  definition of, 21-1, 11
Fuel
  irradiated, transportation of, 21-5, 12
  reprocessing of, 21-3, 20, 21
  spent, shipping cask for, 21-1, 25-27

Gases
  radioactive, sources of, 21-1, 13; treatment of, 21-1, 13, 14

International Atomic Energy Agency
  radioactive waste transfer by, 21-3, 12
Interstate Commerce Commission
  in radioactive waste regulation, 21-5, 6

Labels
  empty, 21-5, 20, 21
  for radioactive material, 21-5, 17; 21-6, 20, 21
  radioactive white-I, 21-5, 17, 18
  radioactive yellow-III, 21-5, 19,20
  radioactive yellow-II, 21-5, 18, 19

Leak testing
of sealed sources, analysis of, 21-7, 9-12; direct, 21-7, 7; for gaseous sources, 21-7, 9; indirect, 21-7, 8; lab procedure for, 21-7, 15, 16; summary of, 21-7, 12, 13
London Convention on Prevention of Marine Pollution by Dumping of Wastes and Other Matter
on radioactive waste, 21-3, 17
Low-specific-activity materials
discussion of, 21-6, 16

Memorandum of Understanding
by Department of Transportation and Atomic Energy Commission, 21-3, 11, 12

National Environmental Policy Act of 1969
and Environmental Impact Statement, 21-3, 19
Nuclear Regulatory Commission
radiation standard by, 21-3, 9
waste, regulation by, 21-3, 3, 4; research by, 21-3, 9, 17, 18
and waste transportation, 21-3, 13

Office of Hazardous Materials
in waste regulation, 21-5, 7

Placarding
of highway vehicles, 21-5, 23, 24
of radioactive carriers, 21-6, 23
of rail vehicles, 21-5, 24, 25
Plutonium
incinerator recovery of, 21-1, 24
Public Laws
in waste regulation, 21-5, 8, 9

Radioactive gases
sources of, 21-1, 13
treatment of, 21-1, 13, 14
Radioactive material
carriers for. See Carriers.
fissile classes of, 21-6, 19, 20
forms of, 21-6, 9, 10
packaging of, 21-6, 12-16
shipper requirements for, 21-6, 22
shipping requirements for, 21-6, 25, 26
transport of, 21-6, 6-9
types of, 21-6, 11
Radioactive waste
from activation products, 21-1, 12
in air, 21-2, 6, 7, 9
burial sites of, 21-1, 24, 25
chemical dangers of, 21-2, 5
classification of, 21-2, 4
container for. See Waste container.
disposal of, 21-1, 1
from fission products, 21-1, 11, 12
from fuel cycle, 21-1, 8, 9; Table 21-1-1 (21-1, 10)
from fuel reprocessing, 21-1, 12
gaseous, activity concentration of, 21-2, 18-22; airborne contamination by, 21-2, 6, 7; classification of, 21-1, 8; nonparticulate acticity removal from, 21-1, 28, 29
identification of, 21-2, 3, 4
initiation of, 21-3, 18, 19
liquid, classification of, 21-1, 6, 7; concentration and containment of, 21-1, 15-19; dilution of, 21-1, 19-21; solidification of, 21-1, 19
low-level, transportation of, 21-5, 31-34
management of. See Waste management.
nature of, 21-1, 5
packaging of, 21-5, 11, 21, 22
radionuclide identification in, 21-4 3-5
regulation of, agencies for, 21-5, 7; initiation of, 21-3, 18, 19; license for, 21-3, 11; by states, 21-3, 13-15; in territorial water dumps, 21-3, 15, 16
research on, 21-3, 17, 18
safety considerations for, 21-2, 5
sampling of, 21-2, 5
solid, classification of, 21-1, 7, 8; compaction of, 21-1, 22; disposal of, 21-1, 22-28; incineration of, 21-1, 24; salt dome storage of, 21-1, 27
sources of, 21-1, 8-12, 14
transport of, 21-3, 26. See also Waste transport.
Radioactivity
natural, 21-1, 9
Radioisotope
identification of, 21-4, 18-20
Radionuclides
transport groups of, 21-4, 4, 29-34
Retrievable surface storage facilities for solid wastes, 21-1, 25, 26
Riffer
in sampling, 21-2, 27

Salt dome
radioactive waste storage in, 21-1, 27
Sample
activity of, 21-2, 29
analysis of, 21-2, 28, 29
containers, for radioactive liquid wastes, 21-2, 22, 23
preparation, for radioactive waste, 21-2, 28
representative, 21-2, 3, 23
Sampler
gas, 21-2, 17, 18
Sample size
radioactive waste, liquid, 21-2, 25, 26; solid, 21-2, 27
Sampling
continuous, 21-2, 15, 16
intermittent, 21-2, 14, 15
procedures, for particlates, 21-2, 13 14; for gaseous waste, 21-1, 12, 13

of radioactive metals, 21-2, 27
results of, 21-2, 29
train, 21-2, 10-12
waste, gaseous, 21-2, 31, 32;
liquid, 21-2, 24, 32-24;
solid, 21-2, 26
Sealed sources
alpha, 21-7, 3, 4
beta, 21-7, 4
definition of, 21-7, 1
description of, 21-7, 3
gamma, 21-7, 5
neutron, 21-5, 5, 6
regulation of, 21-7, 6, 7
safety for, 21-7, 6
Security seal
for radioactive material, 21-6, 23
Shadow shield
description of, 21-7, 7
Shipper
of radioactive waste, 21-5, 21-25
Shipping papers
for radioactive material, 21-6, 22, 23
for radioactive waste, 21-5, 22, 23, 25
Smear(s)
activity, 21-4, 14-17
collection, 21-4, 13, 14
non-compliance, 21-4, 15, 16
testing, 21-4, 13, 19, 20
Stowage control
for radioactive shipments, 21-6, 18, 19
Supremacy Clause
and state nuclear waste regulation, 21-3, 14

Tariff
discussion of, 21-6, 8
Transportation Safety Act
discussion of, 21-6, 5
Transport index
discussion of, 21-6, 16, 17

United Nations Law of the Sea Convention on the High Seas
on radioactive waste, 21-3, 16
Uranium
separation of, 21-1, 31, 32

Waste. See Radioactive waste.
Waste container(s)
decontamination of, 21-4, 9
ion chamber survey of, 21-4, 7, 8
labels for, 21-5, 17
radiation fields of, excess, 21-4, 9;
external, 21-4, 7
surface, activity of, 21-4, 10; survey of, 21-4, 10-12
Waste management
activities of, 21-3, 6,7
of fuel processing, 21-3, 22
functions of, 21-3, 24
government organization in, 21-3, 27
levels of, 21-3, 25
methods for, 21-1, 14, 15
monitoring of, 21-3, 22, 23
ocean in, 21-3, 26, 27
responsibility for, 21-3, 7, 8
of transuranic material, 21-3, 8
short-term, 21-3, 25
system for, 21-1, 29, 30
Waste transport
on highways, 21-5, 15
in-state, 21-5, 12
by railroad, 21-5, 13, 15, 16
regulations on, 21-5, 10, 11; catagories for, 21-5, 5; purposes of, 21-5, 3
safety in, 21-5, 6
by truck, 21-5, 12, 13
by water, 21-5, 14, 16